DRAFT SITE WIDE FEASIBILITY STUDY
TECHNICAL MEMORANDUM NO. 3: VAPOR INTRUSION ASSESSMENT AND MITIGATION

Philip Services Corporation
Georgetown Facility
Seattle, Washington

May 2006

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ACRONYMS AND ABBREVIATIONS

1,1-DCE	1,1-dichloroethylene
1Q06	1st Quarter 2006
2Q02	2nd Quarter 2002
3Q02	3rd Quarter 2002
AF	Adjustment Factor
ASTM	American Society for Testing Materials
BASE	Building Assessment Survey & Evaluation
bgs	Below Ground Surface
CCEF	Cancer Cumulative Exceedance Factor
CEF	Cumulative Exceedance Factor
cfm	Cubic Feet Per Minute
COPC	Constituent of Potential Concern
CUL	Cleanup Level
DTSC	California Department of Toxic Substances Control
Ecology	Washington State Department of Ecology
EF	Exceedance Factor
facility	Former Georgetown Facility Located at 734 South Lucile Street Seattle, WA
FS	Feasibility Study
GIVF	Groundwater-to-Indoor Air Volatilization Factor
HCIM	Hydraulic Control Interim Measure
HHERA	Human Health and Ecological Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
HVAC	Heating, Ventilation and Air Conditioning
IDW	Inverse Distance Weighting
IM	Interim Measure
ISCST3	Industrial Source Complex Short Term Version 3
IPIM	Inhalation Pathway Interim Measure
IPIMAL	Inhalation Pathway Interim Measure Action Level
IRIS	Integrated Risk Information System
JEM	Johnson Ettinger Model
Long-Term O & M Plan	Verification of Depressurization System Effectiveness and Long-Term Operations and Maintenance Plan for Inhalation Pathway Interim Measure
MADEP	Massachusetts Department of Environmental Protection
MDH	Minnesota Department of Health
MTCA	Model Toxics Control Act (Chapter 173-340 Washington Administrative Code. February 12, 2001)
NCEA	National Center for Environmental Assessment
NCEF	Noncancer Exceedance factor
NCCEF	Noncancer Cumulative Exceedance Factor

ACRONYMS AND ABBREVIATIONS

NHEXAS	National Human Exposure Assessment Survey
NJDEP	New Jersey Department of Environmental Protection
NYSDOH	New York State Department of Health
OSWER	Office of Solid Waste & Emergency Response
Pa	Pascal
PCAMP	Pre-Corrective Action Monitoring Program
PCE	Tetrachloroethene or Tetrachloroethylene
Permit	The Georgetown Facility's RCRA Hazardous/Dangerous Waste Permit (WAD 00081 2909)
PLP	Potentially Liable Party
PRAL	Preliminary Remedial Action Level
PSC	Philip Services Corporation
PTC	PIONEER Technologies Corporation
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
SAD	Stone-Drew/Ashe & Jones
CRWQB	California Regional Water Quality Board
site	Georgetown Facility and Surrounding Area
SMDS	Sub-membrane Depressurization System
SSDS	Sub-slab Depressurization System
SWFS	Site Wide Feasibility Study
SWFS Area	The Area addressed by the SWFS
SWFS Tech Memo 3	Feasibility Study Technical Memorandum 3
TC	Target Constituent
TCE	Trichloroethene or Trichloroethylene
THRA	Trichloroethylene Health Risk Assessment: Synthesis & Characterization
ug/L	Micrograms per liter
ug/m^3	Micrograms per cubic meter
USEPA	United States Environmental Protection Agency
VI	Vapor Intrusion
VIAM	Vapor Intrusion Assessment and Mitigation
VIRL	Vapor Intrusion Remediation Level
VOC	Volatile Organic Constituent
WAC	Washington Administrative Code
WADOH	Washington State Department of Health

SECTION 1 – INTRODUCTION

PIONEER Technologies Corporation (PTC) prepared this Technical Memorandum on behalf of Philip Services Corporation (PSC) to document work completed to date for the revised Site Wide Feasibility Study (SWFS) for the Philip Services Corporation (PSC) Georgetown facility[1]. This SWFS is intended to meet corrective action provisions of the PSC Georgetown facility Resource Conservation Recovery Act (RCRA) Part B Permit and the requirements of the Washington State Model Toxics Control Act (MTCA). The Permit, as issued under the authority of the Washington Department of Ecology (Ecology), covers the regulated areas of the former PSC facility operations. PSC closed these areas (and all dangerous waste operations within these areas) in August 2003 under a closure plan approved by Ecology. At that time, all dangerous waste operations at the facility ceased.

The draft SWFS was submitted to Ecology in September 2005 (Geomatrix, 2005). The area addressed by the SWFS (SWFS Area) includes properties currently owned by PSC, properties adjacent to the PSC properties, and the contiguous areas affected by releases from the facility extending downgradient (west) to Fourth Avenue South (see Figure 1-1). After the Remedial Investigation (RI) Report was completed, releases to soil and groundwater from non-PSC sources were identified downgradient from the facility, near Fourth Avenue South. The specific constituents released from these downgradient sources included many of the constituents of potential concern (COPCs) identified at the facility. These downgradient sources have resulted in an area of co-mingled releases that extend from approximately Fourth Avenue South to the Duwamish Waterway. Due to the presence of these downgradient source areas and the complexity of dealing with impacted groundwater from multiple sources, the scope of the SWFS has been limited, with Ecology's concurrence, to the SWFS Area. Remedial action for the area located hydraulically downgradient from Fourth Avenue South will be addressed separately.

In response to comments received from Ecology on the initial draft SWFS report, PSC and Ecology have agreed to use a collaborative, phased process in preparing the revised draft SWFS report to ensure consensus among PSC, Ecology, and other interested parties on key issues that affect the SWFS. During this process, PSC will develop five separate Technical Memoranda addressing the following topics to satisfy Permit and MTCA requirements for the complete SWFS:

- SWFS Technical Memorandum 1: Cleanup Levels, Constituents of Concern, Point of Compliance, Fate and Transport Modeling, and Corrective Action Schedule (submitted March 2006)

[1] Throughout this memorandum, the term "facility" will be used to refer to the former Resource Conservation and Recovery Act (RCRA) dangerous waste operations located at 734 South Lucile Street, owned and operated by PSC. The term may also include certain properties, adjacent to the former dangerous waste facility property, acquired by PSC following closure of the dangerous waste operations in August 2003 (e.g., adjacent property to the northwest formerly owned by The Amalgamated Sugar Company (TASCO) that was impacted by historical releases from the PSC facility). The facility RCRA Part B permit (Permit) requires PSC to perform corrective action beyond the boundaries of the permitted facility to address such releases. The Washington Model Toxics Control Act (MTCA) regulations, Chapter 173-340 WAC, also require PSC to perform cleanup actions to address releases from the facility at "any site or area where a hazardous substance has been deposited, stored, disposed of, or placed, or otherwise come to be located. See WAC 173-340-200. For purposes of this Technical Memorandum, the term "site" includes both the facility and other areas (e.g., TASCO) that have been affected by releases that occurred at the facility.

- SWFS Technical Memorandum 2: Remediation Areas
- SWFS Technical Memorandum 3: Vapor Intrusion Assessment and Mitigation
- SWFS Technical Memorandum 4: Technology Identification and Screening
- SWFS Technical Memorandum 5: Remedial Alternative Development and Evaluation

Ecology approved Technical Memoranda No. 1 on April 12, 2006 Ecology, 2006. SWFS Technical Memoranda No. 2 and No. 3 will be submitted to Ecology in draft form in mid 2006. Following Ecology's review and comment, PSC will revise the draft memoranda as appropriate for final approval by Ecology. SWFS Technical Memorandum No. 4 will be prepared after final approval of both Memoranda No. 2 and 3, and SWFS Technical Memorandum No. 5 will be prepared after final approval of SWFS Technical Memorandum No. 4. PSC will prepare the complete revised draft SWFS following Ecology approval of SWFS Technical Memorandum No. 5 by combining the five memoranda listed above.

This Technical Memorandum documents the vapor intrusion assessment and mitigation (VIAM) component of a Site Wide Feasibility Study (SWFS) for the PSC Georgetown facility.

1.1 BACKGROUND

The Georgetown facility has a history of chemical use and storage dating back at least 50 years. In 1988, the United States Environmental Protection Agency (USEPA) (i.e., the lead regulatory agency at the time) prepared a RCRA Facility Assessment (RFA) and produced a Solid Waste Management Unit Report to evaluate whether or not there had been any releases to the environment. Remedial Investigation (RI) activities (including groundwater, soil, and soil gas investigations) have been ongoing at the facility since 1988. The facility received a RCRA Permit from the USEPA in August 1991, which contained corrective action requirements, including conducting a RCRA Facility Investigation (RFI) to determine the nature and extent of contamination.

In March 2002, Ecology became the lead agency for RCRA corrective actions related to the facility and currently enforces the Permit's corrective action requirements. Ecology manages RCRA corrective actions under the MTCA regulations, which use different terminology from the RCRA regulations (e.g., an RFI under RCRA is referred to as an RI under MTCA). The Final RI Report was submitted to Ecology in November 2003 (PSC, 2003d) and the final addendum to the RI Report was approved by Ecology in December 2004 (Ecology, 2004). The Final Human Health and Ecological Risk Assessment (HHERA) was included in this document (PSC, 2003e).

During an RI process, if it is determined by Ecology or the Permittee (e.g., PSC) that there is a threat to human health or the environment, an interim measure (IM) or an expedited cleanup may be necessary. This IM may not satisfy the requirements of a Final Cleanup Remedy, but it should be consistent with the anticipated Final Cleanup Remedy. Correspondence from the USEPA and Ecology dated June 28, 2001, which modified the corrective action Permit for the Georgetown facility, required that PSC implement groundwater interim measures at the site. In response to this requirement, PSC has implemented hydraulic control interim measure (HCIM) and inhalation pathway interim measure (IPIM) activities.

During 2003 and 2004, PSC implemented the HCIM to provide hydraulic control of the impacted groundwater emanating from the Georgetown facility and to control human exposures to impacted groundwater in any area where exposure may be occurring (URS, 2003). The hydraulic control interim measure (HCIM) required construction of a subsurface barrier wall keyed into the aquitard underlying the site and a pump-and-treat system designed to maintain an inward gradient to contain contaminated groundwater beneath the facility and immediately adjacent properties (see Figure 1-1). The HCIM has proven effective in providing hydraulic control of groundwater in these areas of the site.

In August 2002, PSC submitted the Revised Inhalation Pathway Interim Measures (IPIM) Work Plan (PSC, 2002a) in accordance with Permit requirements for IMs that were incorporated into the Permit. This was in response to a letter from the USEPA and Ecology dated June 28, 2001, which modified the corrective action Permit for the Georgetown facility and required that groundwater interim measures be implemented at the facility. These IPIM activities were focused on addressing VI from groundwater, which is evaluated under the MTCA, pursuant to WAC 173-340-350, 173-340-720(1)(c), 173-340-720(1)(d)(iv), and 173-340-750. The area for determining whether or not IPIMs were warranted was downgradient of the HCIM of the Georgetown facility. The results of the program performed under the Revised IPIM Work Plan were presented in IPIM Technical Memorandum 1 (IPIM Tech Memo 1) (PSC, 2003a) and in subsequent IPIM Technical Memoranda, Quarterly Groundwater Reports, Tier 3 Reports, and Tier 4 Reports.

1.2 PURPOSE

This memorandum (SWFS Technical Memorandum No. 3) presents the VI assessment and mitigation (VIAM) approach and demonstrates how this approach is an integral component of the Final Cleanup Remedy for the site, as defined by MTCA (WAC 173-340-360).

WAC 173-340-360 (2) presents minimum requirements for cleanup actions, but recognizes that cleanup actions will often involve the use of several components at a single site. The VIAM approach is a component of the Final Cleanup Remedy for the site that will be protective of indoor air quality. This tiered approach includes an engineering control that prevents, or mitigates, exposure to volatile organic constituents (VOCs) in indoor air associated with volatilization from groundwater and/or soil. This approach, when used in conjunction with source control (i.e., the HCIM) and remedial actions (e.g., monitored natural attenuation), meets the threshold requirements and other requirements as described under WAC 173-340-360 (2).

1.3 REPORT ORGANIZATION

This report is organized into the following sections:

- **Section 1 – Introduction:** Introduces the VIAM approach, provides the regulatory background leading up to the SWFS, and presents the purpose of Technical Memorandum No. 3.

- **Section 2 – IPIM Approach:** Summarizes the current tiered IPIM approach and Long-Term Monitoring Plan and provides a status of locations evaluated under the IPIM program to date.

- **Section 3 – VIAM Approach:** Outlines the VIAM approach as a component of the Final Cleanup Remedy for the site and provides further discussion regarding the consistency of this approach with current VI guidance documents.

- **Section 4 – Uncertainty Analysis:** Summarizes key uncertainties associated with the VIAM approach and summarizes the results of three sensitivity analyses that evaluate the impact of these uncertainties on risk management decisions and the Final Cleanup Remedy.

SECTION 2 – IPIM APPROACH

This section summarizes the IPIM approach that has been used in the Georgetown Community proximate to the facility since 2002 to assess the potential for VI at commercial and residential buildings to determine whether or not installations of VI mitigation systems are required. This section also summarizes the technical basis for developing groundwater-to-indoor-air volatilization factors (GIVFs) and IPIM actions levels (IPIMALs). The IPIM approach is an integrated approach for evaluating groundwater and indoor air data to determine, through the use of the IPIM Decision Tree, if a building warrants further investigation or action through an IM. The IPIM Decision Tree (see Figure 2-1) is organized into four tiers to allow progressive evaluation of groundwater data and incorporation of site-specific information. The IPIM Decision Tree (described in the Revised IPIM Work Plan [PSC, 2002a]) is also intended to be flexible so that at any time a decision can be made to proceed directly to consult with Ecology regarding the need to implement an IM.

- **Tier 1** – The first tier in the IPIM Decision Tree is to compare groundwater monitoring data to residential-based groundwater IPIMALs on a well-by-well basis. Concentrations that exceed risk benchmarks are contoured to show areas of impact. Residential locations that fall within the areas of impact are identified for further evaluation under Tier 3 of the IPIM Decision Tree.

- **Tier 2** – Commercial/industrial locations are evaluated further under Tier 2 by comparing groundwater monitoring data to commercial-based groundwater IPIMALs on a well-by-well basis. Concentrations that exceed risk benchmarks are contoured to show areas of impact. Commercial/industrial locations that fall within the areas of impact are identified for further evaluation under Tier 3 of the IPIM Decision Tree

- **Tier 3** – Residential and commercial/industrial locations identified in Tier 1 or Tier 2 for review under Tier 3 are evaluated to determine if site-specific data collection (i.e., co-located indoor air, ambient air, sub-slab soil gas, and groundwater) is warranted or if the location should move directly to Tier 4. If the site does not proceed directly to Tier 4, then Tier 3 samples are collected and evaluated, and a Tier 3 Report is developed summarizing the data, risks, and the recommended course of action (i.e., the site is recommended for Tier 4 if Ecology's cancer or noncancer health benchmarks are exceeded; otherwise, the site returns to Tier 1/Tier 2).

- **Tier 4** – Residential and commercial/industrial locations that move to Tier 4 have VI mitigation systems installed in order to eliminate or mitigate VI from groundwater and/or soil.

- **Long-Term Monitoring** – Long-term monitoring is performed to determine whether or not the IPIM depressurization systems are still functioning as designed. Long-term monitoring and maintenance of the IPIMs are performed using annual inspections and a long-term monitoring program including periodic pressure field checks and, in some cases, VOC sampling.

The technical basis for developing IPIMALs and the IPIM Decision Tree is described below.

2.1 TECHNICAL BASIS FOR DEVELOPING IPIMALS

2.1.1 Migration of Soil Gas from Groundwater to Indoor Air

Groundwater in the shallow aquifer in the area of the Georgetown facility is primarily migrating in a west-southwest direction. Under some conditions, VOCs dissolved in the groundwater may migrate through the soil into nearby basements, buildings, and other enclosed spaces[2]. The basic factors that influence the amount of VOCs that migrate from groundwater into indoor air include the following:

- Volatilization from groundwater to soil gas at the water table (i.e., at the groundwater/soil interface).

- Migration of the soil gas via diffusion upward toward buildings and ground surface through the partially saturated soils directly above the water table and through the unsaturated zone (vadose zone).

- Attenuation of COPCs in soil gas within the vadose zone due to abiotic, anaerobic or anaerobic degradation.

- Migration of soil gas vertically through the building foundation via diffusion and advection through cracks or other openings that may serve as entry points for soil gas. The degree of migration through the foundation depends on many factors, including soil type and moisture content directly beneath the structure, building construction type (e.g., basement or slab-on-grade), structural integrity of the building, pressure gradients associated with seasonal effects, the building ventilation system, and the operation of household appliances. Advection is made possible by continuous airflow paths associated with open or incompletely sealed doors and windows, chimneys and other intake/exhaust ports.

- Mixing of indoor air inside the enclosed space with ambient air that is drawn into the building. The degree of mixing depends on the amount of mechanical or forced ventilation, natural ventilation, and infiltration from ambient air.

2.2 DEVELOPMENT OF GIVFS AND GROUNDWATER IPIMALS

PSC developed GIVFs and IPIMALs in order to evaluate the inhalation pathway following the procedures outlined in the Revised IPIM Work Plan (PSC, 2002a), which are presented on Figure 2-2.

2.2.1 Development of GIVFs

The GIVFs were developed in August 2002 based on multi-media sampling performed by PSC at 10 building locations within a mixed residential/industrial neighborhood that is hydraulically downgradient of the Georgetown facility and is most likely impacted by facility-related COPCs[3]. Samples were

[2] People may also be exposed to contaminated soil gases if they are excavating soils in areas where the groundwater is contaminated with VOCs.

[3] The COPCs for the site were identified in the Draft Human Health and Ecological Risk Assessment (Draft HHERA) (PSC, 2001).

collected in accordance with the Revised IPIM Work Plan (PSC, 2002a). Building-specific GIVFs were developed using sets of data collected from multiple locations using the following approach (outlined in the Revised IPIM Work Plan (PSC, 2002a) and IPIM Tech Memo 1 (PSC, 2003a)):

1. Co-located and co-collected groundwater, indoor air, and ambient air data from each location were paired for specific target constituents (TCs)[4].
2. Indoor air sampling results were corrected for background concentrations by subtracting the higher of the potential contributions from indoor air sources[5] and measured ambient air sources.
3. At each location, COPC-specific GIVFs for the TCs were calculated using the following relationship:

$$GIVF_{TC}\frac{(\mu g/m^3)}{(\mu g/L)} = \frac{Corrected\ Indoor\ \ Air\ \ Concentration\ \ (\mu g/m^3)}{Groundwater\ \ Concentration\ \ (\mu g/L)}$$

4. PSC used the most protective (highest) representative GIVF for the TCs (i.e., GIVFTC_max) to derive GIVFs for each remaining COPC (GIVFCOPC) based on the relationship of the physical/chemical properties of the protective TC to the COPC. This relationship is expressed in the form of a COPC-specific adjustment factor (AF) that was determined for each COPC (AFCOPC) by using the Johnson and Ettinger model (JEM) to calculate a ratio based on the COPC-specific difference in migration potential for each COPC (Johnson and Ettinger, 1991; EQM, 2003). The JEM was applied using the site-specific set of parameters introduced in IPIM Tech Memo 1 (PSC, 2003a) to predict the indoor air concentration for a given groundwater concentration (i.e., 1 µg/L) of the COPC (CIndoorCOPC) and the (CIndoorTCMax) which is the TC with the most protective GIVF (i.e., GIVFTC_max). The GIVFCOPC was calculated using the following relationship:

$$GIVF_{COPC}\frac{(\mu g/m^3)}{(\mu g/L)} = GIVF_{TC\_\max}\frac{(\mu g/m^3)}{(\mu g/L)} * \mathrm{AF}_{\mathrm{COPC}}$$

where:

$$\mathrm{AF}_{\mathrm{COPC}} = \left[\frac{C_{IndoorCOPC}}{C_{IndoorTCMax}}\right]$$

Using this approach, $\mathrm{AF}_{\mathrm{COPCs}}$ (proportional to the $\mathrm{C}_{\mathrm{IndoorTCMax}}$) were calculated for the remaining COPCs, which in turn were used to calculate GIVFs.

2.2.2 Development of Groundwater IPIMALs

The IPIMALs for groundwater were calculated using conservative risk-based indoor air action levels and the COPC-specific GIVFs.

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[4] Target constituents are considered the most reliable tracers for representing volatilization of source COPCs from groundwater to indoor air. The basis for selection of these constituents is discussed in the Revised IPIM Work Plan (PSC, 2002a).

[5] The lower of the median or mean of the 25th and 75th percentiles for background indoor air obtained from the National Human Exposure Assessment Survey (USEPA, 1995; Pellizari et. al., 1995) or California Air Resources Board and Total Exposure Assessment Methodology (Clayton and Perritt, 1993) studies.

The IPIMALs are based on the action levels for indoor air developed in the Draft HHERA (PSC, 2001). Exposure parameters used to develop these IPIMALs are presented in Table 2-1 for restricted (commercial/industrial) and unrestricted (residential) scenarios. These action levels were developed such that the maximum indoor air concentrations of each COPC are health protective action levels based on a COPC-specific carcinogenic risk goal of 1E-06 and a hazard quotient of 0.1 for noncarcinogens for both residential and commercial/industrial workers. Table 2-2 presents the indoor air action levels for residential and commercial receptors and the specific exposure assumptions on which these action levels are based. IPIMALs for indoor air were calculated by using the final toxicity values approved by Ecology for use in the RI (PTC, 2005a).

IPIMALs for groundwater were calculated using the IPIMALs for indoor air and the GIVFs, using the following equation:

$$IPIMAL\ Groundwater\ \ (\mu g / L) = \frac{IPIMAL\ IndoorAir\ \ (\mu g / m^3)}{GIVF\ \dfrac{(\mu g / m^3)}{(\mu g / L)}}$$

Table 2-2 also shows the residential and commercial groundwater IPIMALs for each COPC that are used to evaluate quarterly groundwater monitoring results by following the IPIM Decision Tree.

2.3 IPIM DECISION TREE

The IPIM Decision Tree (see Figure 2-1) is organized into four tiers to allow progressive evaluation of groundwater data and incorporation of site-specific information. The area for determining if IMs are warranted (i.e., former RI Area 3)[6], and the Pre-corrective Action Monitoring Program (PCAMP) groundwater monitoring wells applicable to the IPIM, are presented in Figure 2-3. Validated data from each quarterly groundwater monitoring event are compiled and evaluated for purposes of calculating IM cancer cumulative exceedance factors (CCEFs) and noncancer cumulative exceedance factors (NCCEFs) as follows:

- All groundwater data collected from former RI Area 3 (west of Denver Avenue) are included in the evaluation; and
- Censored data (i.e., non-detected results) are assigned one-half the reporting limit for comparison purposes, in accordance with the Revised IPIM Work Plan (PSC, 2002a).

Residential buildings are evaluated in Tier 1. Commercial/industrial locations are evaluated in Tier 2. The determination of whether or not a building is a residential use-type versus commercial use-type is based on preliminary field verifications by PSC and PTC personnel. Additional field verifications may be conducted prior to making a final determination of building use-types and follow-up actions.

[6] Former Area 3 is defined in IPIM Tech Memo 1 and initially included locations downgradient of the HCIM. Area 3 was ultimately confined to the SWFS Area due to the presence of downgradient source areas and the complexity of dealing with impacted groundwater from multiple sources.

2.3.1 Tier 1 – Determination of Potential Impacts to Residential Buildings

The first tier in the IPIM Decision Tree is to compare PCAMP groundwater monitoring data from former RI Area 3 to residential-based groundwater IPIMALs on a well-by-well basis.

Residential-based and commercial-based groundwater IPIMALs developed in IPIM Tech Memo 1 are presented in Table 2-2. COPC-specific exceedance factors (EFs) for each location are calculated using the following equation:

$$EF = \frac{C_{groundwater}}{\text{Residential}_{IPIMAL}}$$

where:

Parameter	Description
$C_{groundwater}$	Concentration in each groundwater well (ug/L).
$\text{Residential}_{IPIMAL}$	Residential-based IPIMAL for groundwater (ug/L), based on a carcinogenic risk of 1E-06 and a hazard quotient (HQ) of 0.1.
EF	Exceedance Factor.

Under Tier 1, residential CCEFs and NCCEFs for each monitoring well in the IPIM area are calculated by summing the EFs for individual cancer and noncancer COPCs, respectively. Residential CCEFs and NCCEFs calculated for quarterly monitoring well data are summarized in Section 2.5. A CCEF and NCCEF of 10 indicate that exposure to indoor air concentrations associated with volatilization from groundwater near the sample station could potentially result in a cumulative risk of 1E-05 or a hazard index (HI) of 1[7], respectively.

Residential CCEFs and NCCEFs for COPCs detected at each monitoring well or direct push station are contoured using the Inverse Distance Weighting (IDW) interpolation method. IDW is used to create a grid of nodes (250-foot radius upgradient/downgradient of each well and 100-foot cross gradient from each well) where the value of each node is determined by interpolating values from known sample results. With IDW, data are weighted during interpolation such that the influence of one point relative to another declines with distance from the grid node. For example, areas closer to the measured data point are given more weight than more distant areas. As a result, there is much more confidence in contours generated for areas with higher sample density versus areas (e.g., west of 6th Avenue) where there are fewer samples. The IDW input parameters are summarized in Table 2-3.

A key advantage of applying the IDW is the ability to incorporate anisotropy into the interpolation. Many physical processes, such as groundwater flow, have preferred orientations (i.e., anisotropy). For example, groundwater in former RI Area 3 flows in a west-southwest direction. This preferred flow direction is incorporated into the IDW model by setting an appropriate anisotropy angle. During the gridding process, points oriented in the direction of flow are weighted more heavily than other points, thus reducing the uncertainty associated with the interpolation algorithm used to estimate the area of influence.

[7] Per WAC 173-340-700(5)(b)(c), PSC may elect to evaluate the COPC-specific toxicity information to determine if it is appropriate to segregate the hazard quotients (HQs) (if the CEF for noncarcinogens is greater than 10). If the toxicity information indicates that it is appropriate to segregate the HQs, the decision rules for evaluating the segregated HIs are as follows: If any of the segregated HIs are greater than 1, the building will be proposed for Tier 4. If all of the segregated HIs are less than 1, the building will not be evaluated further until the next round of groundwater sampling. Segregation of HIs will be done with the COPC-specific prior approval of Ecology.

Residential locations that fall within the contours representing CCEFs or NCCEFs for COPCs detected in groundwater exceeding 10 are proposed for further evaluation under Tier 3 of the IPIM Decision Tree (see Figure 2-1). These locations have a potential cumulative inhalation cancer risk due to VI of 1E-05 or greater and/or a HI of 1 or greater. All locations are re-evaluated after the next quarterly groundwater monitoring event.

2.3.2 Tier 2 – Determination of Potential Impacts to Commercial Buildings

The approach for developing commercial-based IPIMALs is identical to the approach used to develop the residential-based IPIMALs except that the commercial exposure assumptions are used instead of residential exposure assumptions. Commercial/industrial locations are evaluated under Tier 2 by comparing COPCs detected in groundwater to commercial-based IPIMALs as presented in Table 2-2. Commercial/industrial locations that fall within the contours representing CCEFs or NCCEFs for COPCs detected in groundwater exceeding 10 are proposed for further evaluation under Tier 3 of the IPIM Decision Tree (see Figure 2-1). These locations have a potential cumulative inhalation cancer risk due to VI of 1E-05 or greater and/or a HI of 1 or greater. All locations are re-evaluated after the next quarterly groundwater monitoring event.

2.3.3 Tier 3 – Site-Specific Sampling

Residential and commercial/industrial locations identified in Tier 1 or Tier 2 for review under Tier 3 are evaluated to determine if site-specific data collection is warranted or if the location should move directly to Tier 4. Each location is evaluated independently. Site-specific, co-located, and contemporaneous groundwater, sub-slab, soil gas, indoor air, and ambient air samples are collected at buildings identified as Tier 3 locations in Tier 1 and Tier 2.

PSC conducts all sampling and analysis in accordance with the Revised IPIM Work Plan (PSC, 2002a). PSC compiles and evaluates the data to determine if the location should proceed to Tier 4, as follows:

1. One-half of the reporting limit is assumed for non-detected results in indoor air. For comparison purposes, all data are presented in three ways: CCEFs and NCCEFs calculated for all data, CCEFs and NCCEFs calculated using just non-detected data, and CCEFs and NCCEFs calculated using just detected data.

2. Per the Revised IPIM Work Plan (PSC, 2002a), indoor air concentrations are corrected by subtracting the maximum detected ambient air concentration from the maximum detected indoor air concentration, to account for the contribution of ambient air to the measured indoor air concentrations[8].

Noncancer exceedance factors (NCEFs) are calculated by dividing the corrected indoor air concentrations by noncancer-based indoor air IPIMALs. Cancer exceedance factors (CEFs) are calculated by dividing the corrected indoor air concentrations by cancer-based indoor air IPIMALs. The individual NCEFs and

[8] Literature values for background indoor air sources (i.e., potential contributions from non-VI related indoor air sources) were originally proposed to be used to “correct” measured indoor air concentrations in addition to ambient air. However, Ecology ultimately did not agree to this adjustment (see March 3, 2003 letter from Ed Jones [Ecology] to Carolyn Mayer [PSC])) (Ecology, 2003).

CEFs are summed to provide the NCCEF and CCEF. CEFs are calculated using the same relationship as used for Tier 1 and Tier 2, but indoor air data are compared to indoor air IPIMALs, as follows:

$$EF = \frac{C_{Indoor\ air\_Corr}}{\text{Residential or Commercial}_{IPIMAL}}$$

where:

Parameter	Description
$C_{Indoor\ air\_Corr}$	Corrected maximum indoor air at location (µg/m^3). These concentrations are determined by subtracting the maximum measured ambient (outdoor) air concentration from the maximum indoor air concentration.
Residential or $\text{Commercial}_{IPIMAL}$	Residential-based or commercial-based IPIMAL for indoor air (µg/m^3), based on a carcinogenic risk of 1E-06 and HQ of 0.1.
EF	Exceedance Factor.

The CCEFs and NCCEFs for each location are calculated by summing the EFs for individual cancer and noncancer COPCs. A CCEF/NCCEF of 10 indicates that exposure to indoor air concentrations could potentially lead to a cumulative risk of 1E-05 or an HI of 1.

The NCCEF and CCEF for each location is compared to Ecology's noncancer and cancer benchmark of 10. Locations with a NCCEF and/or CCEF greater than 10 are recommended for further evaluation to determine if the location should proceed to Tier 4. All other buildings are re-evaluated when the next round of groundwater sampling is performed.

2.3.4 Tier 4 – Inhalation Pathway Interim Measures

Locations proposed for evaluation under Tier 4 of the IPIM Decision Tree are selected based on the results of the Tier 3 analysis and discussions with Ecology[9]. Tier 3 sampling is conducted on a subset of buildings having exceedances of groundwater CCEFs and NCCEFs. When Tier 3 sampling indicates that a Tier 4 IPIM is warranted, those buildings in close proximity (where Tier 3 sampling was not conducted) are also identified for Tier 4 IPIM installations.

Prior to installation of a Tier 4 VI mitigation system, PSC negotiates access agreements with the property owners at each location. These access agreements define the responsibilities of PSC and the property owners as follows:

- PSC:
  - Install and provide maintenance of the system; and
  - Monitor the performance of the system.
- Property Owner:

[9] It may be decided that some buildings should proceed directly to Tier 4 following the Tier 1 or Tier 2 evaluation.

- Provide PSC and its contractors with access to the property to perform maintenance of the systems;
- Receive instruction on how to monitor the system to ensure it is operating properly; and
- Contact PSC if the system is not operating properly.

The notification and coordination process implemented between PSC and the property owners is a critical component of the effective operation of the Tier 4 systems.

2.3.4.1 Depressurization System Installation

The *Depressurization Design Document: A Supplemental Inhalation Pathway Interim Measures Work Plan* (Depressurization Design Document) was submitted to Ecology in May 2003 (PSC, 2003b). This document describes how the IPIMs are implemented at buildings that have moved to Tier 4. The IPIMs implemented at each property consist of either a sub-slab depressurization system (SSDS) and/or a sub-membrane depressurization system (SMDS), which are designed to be consistent with the American Society for Testing Materials (ASTM) E2121 (ASTM, 2003) and the USEPA's Radon Mitigation Standards (USEPA, 1993; USEPA, 1994b).

The purpose of subsurface ventilation is to depressurize the ground immediately below the slab, which is achieved by using exhaust fans designed to generate sufficient pressure to prevent the flux of air from the soil, through the slab, and into the building. This type of system has been designed for a wide variety of VOCs that migrate through soil, largely through diffusion.

The SSDS decreases the pressure below the building slab so that pressure inside the building is higher, thus, any flow of air and any VOCs between the building and the slab are forced downward out of the building and into the slab. A fan pulls the air/VOCs from the subsurface, and vents them to the ambient air.

For buildings with crawl spaces, VOCs are removed as air is drawn into perforated pipe positioned beneath a vapor barrier (i.e., SMDS). The perforated pipe is attached to an exhaust fan that creates a pressure differential sufficient to direct air into the pipe, where it is eventually vented to the ambient air.

Prior to installation, diagnostic testing is performed to determine the size of the depressurization system (i.e., how many fans and associated exhaust systems) that is required for each building. Once complete, a site-specific design document is developed according to the *Supplemental IPIM Work Plan Depressurization System Design Document* (PSC, 2003c).

2.3.4.2 Confirmation of VI Mitigation System Effectiveness

System verification is performed in accordance with the *Depressurization Design Document and the Verification of Depressurization System Effectiveness and Long Term Operations and Maintenance Plan for Inhalation Pathway Interim Measure* (Long-Term O&M Plan), submitted to Ecology in April 2005 (PSC, 2003b, 2005a). System verification is performed after installation of the SSDS at the locations with basements or slab-on-grade construction to ensure that a negative pressure differential of at least one

Pascal (Pa) is achieved across the extent of the slab[10]. Once the pressure field is confirmed following system start-up, monitoring of the in-line pressure gauge (manometer) is considered an adequate indicator of satisfactory system operation (MADEP, 1995).

For crawl space SMDS, it is not possible to measure the extent of the negative-pressure field. However, additional perforated pipe beneath the membrane serves to extend the suction field beneath the liner, and to increase airflow and movement of VOCs into the pipes and out of the subsurface. The primary way to measure the effectiveness of an SMDS is through inspection of the manometer installed on the exhaust pipe. At installation, manometer readings taken right above the sub-membrane systems should range from 220 to 360 Pa, which is within the guidelines for radon mitigation (USEPA, 1993). The large volume of air being exhausted from under the membranes (110 to 180 cubic feet per minute [cfm]) provides further indication that crawl space areas are being sufficiently ventilated.

To provide additional verification that the established pressure differential is adequate for VOC mitigation, VOC sampling is performed in representative buildings with basement/slab-on-grade construction. At each building, one basement or ground floor indoor air, ambient air and groundwater sample is collected to compare post-installation VOC concentrations with pre- SSDS installation concentrations. Samples are collected according to the methodology specified in the Revised IPIM Work Plan (PSC, 2002a) and site-specific Tier 3 Sampling and Analysis Plans. Table 2-4 presents a schedule for planned post-installation VOC sampling.

Note: Pre- and post-mitigation sampling of VOCs is limited by the influence of background/ambient air concentrations that may mask concentrations of VOCs emanating from soil gas and make it difficult to show decreasing trends in response to the IPIM. Therefore, no specific analytical "criteria" are presented in the Long-Term O & M Plan (PSC 2005a) to assess the effectiveness of the depressurization systems.

2.4 LONG-TERM O & M PLAN

The purpose of Long-Term O & M Plan (PSC, 2005a) is to determine whether or not the IPIM depressurization systems are still functioning as designed. Long-term monitoring and maintenance of the IPIMs are performed using annual inspections and a long-term monitoring program including periodic pressure field checks and/or VOC sampling. Additional evaluations may be performed if a substantial change in conditions indicates a potential impact to system performance.

2.4.1 Annual Inspections

Annual inspections take place during the second quarter and fourth quarter of each year, depending on the accessibility of each building. If the annual inspection indicates that a change in conditions has occurred, additional steps may be performed to determine whether or not the IPIM is still working effectively or is in need of modifications. The criteria for determining whether or not an SSDS or SMDS needs to be re-evaluated to confirm system effectiveness, includes the following:

1. A significant structural change in the building (e.g., remodeling that can introduce additional pathways of vapor migration);

[10] This pressure differential has been shown to be effective in radon mitigation projects, and is below the five Pa pressure differential that, according to EPA (USEPA, 1994b), can lead to backdrafting.

2. A significant increase in groundwater concentrations (e.g., 10 fold increase in the cumulative inhalation risk/hazard) in the vicinity of the building as indicated by the quarterly groundwater sampling performed by PSC;
3. Changes in the mitigation system from the previous reporting period; and/or
4. Problems associated with a system's operation and maintenance.

Additional steps that may be taken to evaluate the impact of a change in conditions are discussed in the Long-Term O & M Plan (PSC, 2005a) and may include:

- Pressure field extension measurements for SSDS to confirm whether or not a negative pressure field still extends under the entire slab and meets the minimum performance standards at the most distal points (at least one Pa). Results are compared with post-installation IPIM measurements. Results that are within ±20 percent of the post-installation measurements indicate that the system is working effectively (PTC, 2004);

- Smoke flow visualization tests to qualitatively establish that an adequate suction field has been established at the perimeter of the slab; and/or

- Crawl space or basement/ground floor indoor air and ambient air sampling to compare VOC concentrations with pre- and/or post-IPIM concentrations.

2.4.2 Long-Term Monitoring Program

The long-term monitoring program consists of periodic measurements of the negative pressure field extension and/or VOC sampling. The IPIM sampling groups, proposed sampling locations, sampling timeframe, and type of sampling to be conducted are presented in the Long-Term O & M Plan (PSC, 2005a). The general sampling approach is the following:

- Collect IPIM VOC samples annually at locations in close proximity and downgradient of the Georgetown facility.

- Collect negative pressure-field extension readings biennially at all SSDS locations.

- Collect VOC samples periodically at SMDS locations[11].

VOC sampling may be conducted as part of annual inspections or as part of long-term monitoring. The data obtained during the annual inspections or long-term monitoring are compared with pre- and post-IPIM SSDS/SMDS installation VOC sampling results and IPIMALs. If the resulting cumulative inhalation risk/hazard is greater than 10 times the previous SSDS/SMDS VOC sampling results, or the IPIM risk/hazard threshold is exceeded, then PSC makes a preliminary determination as to whether or not the SSDS/SMDS installation needs to be modified (e.g., installing additional fan(s), sealing cracks in the slab, et cetera) to ensure that it is reducing indoor air concentrations of VOCs associated with VI from

[11] In lieu of sampling crawl space air for VOCs at some SMDS locations, PSC may instead collect a direct push groundwater sample in the immediate vicinity of the building.

groundwater below Ecology's health risk benchmarks. Results of VOC sampling and a draft determination will be presented in a brief technical memo to Ecology for review prior to finalizing a follow up course of action. This memo is provided to Ecology within 30 days of receiving the validated analytical results.

The results of each annual inspection are presented in the second and fourth Quarterly Groundwater Monitoring Reports for that year.

2.4.3 IPIM Implementation Program Results

The results of implementation of the IPIM are presented below:

- **Tier 1 and Tier 2** – Every quarter, CCEFs and NCCEFs are calculated for each well[12]. A summary of these results for each well is presented in Table 2-5a for Tier 1 (residential) and 2-5b for Tier 2 (commercial/industrial), respectively. Table 2-5a and 2-5b also include the results of the most recent quarterly monitoring event, 1st quarter 2006 (1Q06). Figures 2-4 and 2-5 provide a comparison of residential and commercial CCEFs >10 for 1Q06 monitoring results with previous monitoring results. Only CCEFs are presented because the NCCEFs are co-located with the CCEFs. As shown on Figures 2-4 (for residential) and 2-5 (for commercial), there are no new building footprints that appear to be potentially impacted by VI from groundwater in 1Q06.

- **Tier 3 and Tier 4** – Buildings that fall within the contours shown on Figure 2-4 and 2-5 are considered to be of potential concern and move into the Tier 3 evaluation. In the Tier 3 evaluation, a subset of the buildings of concern is sampled for groundwater, sub-slab and/or soil gas, indoor air, and ambient (outdoor) air. Results of this evaluation are used to identify those buildings requiring installation of a VI mitigation system under Tier 4 of the IPIM program. Because many of the residences are in close proximity to each other and are represented by the same groundwater monitoring well(s), Tier 3 results from a few representative locations are used to identify the broader range of buildings that require installation of a VI mitigation system. VI mitigation system installation has been completed in those buildings where groundwater and/or indoor air IPIMALS were exceeded, or based on the results of Tier 3 sampling in adjacent buildings. Those buildings where VI mitigation systems have been installed are included in the Long-Term O & M Plan, and are inspected annually, which includes periodic air sampling at some locations. A summary of the status of all of the buildings evaluated beyond Tier 1 and Tier 2 screening is presented in Table 2-6. Figure 2-6 shows the current status of each building location evaluated within the IPIM program.

2.5 NON-PSC SOURCES IMPACTING GROUNDWATER IN THE GEORGETOWN COMMUNITY

The Georgetown community located proximate to PSC has a long history of commercial/industrial use. Many of the past and current businesses have used TCE and other materials containing COPCs. During PSC's efforts to further characterize the nature and extent of contamination in groundwater in the

[12] For the monitoring wells not sampled during a quarterly monitoring event, groundwater monitoring results are used from the most recent round of sampling at each of these wells for the interpolation.

Georgetown community, additional sources of COPCs impacting groundwater. These sources were identified by:

- Elevated concentrations of COPCs (including TCE) in the watertable zone immediately downgradient of the potential non-PSC sources;
- Researching historical records, where available, regarding historic land-use (e.g., manufacturing products/processes) and COPC use at the suspected non-PSC sources; and
- Collecting additional direct push groundwater samples upgradient and downgradient of the suspected non-PSC sources.

If the concentrations of COPCs in groundwater immediately downgradient of these locations were significantly higher than the concentrations measured in groundwater samples collected immediately upgradient of these locations, then the location was identified as a non-PSC source with impacts to groundwater. Using this process, the following non-PSC sources have been identified, to-date:

- **Art Brass Plating** – Identified as 312/318 South Findlay Street on Figure 2-6. The mailing/office address is 5516 3rd Avenue South. This location also has COPCs detected in vadose zone soil.
- **Blaser Die Casting** – Identified as 309 South Orcas Street and 5700 3rd Avenue South on Figure 2-6.
- **Capital Industries** – Identified as 111 South Mead Street and 316 South Fidalgo Street on Figure 2-6. The mailing/office address is 5801 2nd Avenue South. This location also has COPCs detected in vadose zone soil.

These additional non-PSC sources of impacts to groundwater are located on a north-south axis along 4th Avenue South, immediately west of the of the SWFS area (see Figure 2-6). The responsibility for IPIM investigation/mitigation for buildings located downgradient of these sources have or will be transferred to the appropriate upgradient PLP(s) as determined by Ecology (see Table 2-6 for a current list of these locations).

2.6 IPIM PROGRAM SUMMARY

The key components of the IPIM Program are summarized below:

- **GIVF Study** – The GIVF study resulted in development of groundwater and indoor air concentrations (IPIMALs) that could be used to screen for locations of potential concern for VI.
- **Tier 1** – Quarterly monitoring well and recent direct push sample groundwater monitoring data are compared to residential-based groundwater IPIMALs on a well-by-well/point-by-point basis. Concentrations that exceed risk benchmarks established by Ecology are contoured to show areas of impact. Residential locations that fall within the areas of impact are identified for further evaluation under Tier 3 of the IPIM Decision Tree.

- **Tier 2 –** Commercial/industrial locations are evaluated further under Tier 2 by comparing groundwater monitoring data to commercial-based groundwater IPIMALs on a well-by-well basis. Concentrations that exceed risk benchmarks established by Ecology are contoured to show areas of impact. Commercial/industrial locations that fall within the areas of impact are identified for further evaluation under Tier 3 of the IPIM Decision Tree

- **Tier 3** – Residential and commercial/industrial locations identified in Tier 1 or Tier 2 for review under Tier 3 are evaluated to determine if site-specific data collection (i.e., co-located indoor air, ambient air, sub-slab soil gas, and groundwater) is warranted or if the location should move directly to Tier 4. If the site does not proceed directly to Tier 4, then Tier 3 samples are collected and evaluated, and a Tier 3 Report is developed summarizing the data, risks, and the recommended course of action (i.e., the site is recommended for Tier 4 if Ecology's cancer or noncancer health benchmarks are exceeded. Otherwise, the site returns to Tier 1/Tier 2).

- **Tier 4 –** Residential and commercial/industrial locations that move to Tier 4 have VI mitigation systems installed in order to eliminate or mitigate VI from groundwater and/or soil.

- **Long-Term Monitoring** – Long-term monitoring is performed ensure that depressurization systems are still functioning as designed.

- **Non-PSC Sources** – IPIM responsibilities for properties with VI or potential VI issues that are unrelated to PSC are transferred to the appropriate potentially liable party (PLP).

SECTION 3 – VIAM APPROACH

The purpose of this section is to present the VIAM approach, which will be a component of the Final Cleanup Remedy for the site. This approach is very similar to the IPIM approach and Long-Term O & M Plan presented in Section 2. This section is organized as follows:

- Section 3.1 summarizes the VIAM approach, focusing primarily on the changes to the IPIM approach that have been incorporated into the VIAM approach.
- Section 3.2 presents an evaluation of the VIAM approach as a component of the Final Cleanup Remedy for the site under MTCA.
- Section 3.3 presents an evaluation of the VIAM approach relative to current VI guidance.

3.1 SUMMARY OF THE VIAM APPROACH

The VIAM approach consists of sequential tiers (or steps) for assessing data and determining whether or not a VI mitigation system needs to be installed in a building. Determinations for the appropriate course of action are based on the VIAM Decision Tree, shown in Figure 3-1. The approach consists of five tiers that correspond to specific risk-management decisions that are focused on protecting residents and workers from VI. The groundwater and indoor air VI Remediation Levels (VIRLs) used in the VIAM Tiered evaluations are identical to the IPMALs presented in Section 2. However, they are redefined as VIRLs in the VIAM, per WAC 173-340-355 and WAC 173-340-750(d) in order to be consistent with development of cleanup action alternatives that include remediation levels. The VIAM approach applies to the SWFS area illustrated on Figure 1-1. Consistent with the approach proposed in the Draft SWFS Report and SWFS Tech Memo 1 (Geomatrix, 2006), remedial action for the area downgradient from Fourth Avenue South will be addressed separately.

3.1.1 Tier 1 – Compare Groundwater Data to Remediation Levels for Residential Exposures

The VIAM Tier 1 approach for locations within the SWFS area is identical to the IPIM Tier 1 approach presented in Section 2.3.1.

3.1.2 Tier 2 – Compare Groundwater Data to Remediation Levels for Commercial/Industrial Exposures

The VIAM Tier 2 approach for locations within the SWFS area is identical to the IPIM Tier 2 approach presented in Section 2.3.2.

3.1.3 Tier 3 – Site-Specific Sampling

The VIAM Tier 3 approach for locations within the SWFS area is identical to the IPIM Tier 3 approach presented in Section 2.3.3, with the following modifications:

- As recommended by New York State Department of Health (NYSDOH) Draft VI Guidance (NYSDOH, 2005) and New Jersey Department of Environmental Protection (NJDEP) VI Guidance (NJDEP, 2005), site-specific sampling of indoor air will be performed during the typical heating season (i.e., November through March) unless time-critical determinations are needed.

3.1.4 Tier 4 – VI Mitigation

The VIAM Tier 4 approach is identical to the IPIM Tier 4 approach presented in Section 2.3.4. In addition, long-term monitoring of VI mitigation systems will follow the procedures outlined in the Long-Term O & M Plan (PSC, 2005a), as summarized in Section 2.4. Post-installation confirmatory sampling will be performed according to the schedule outlined in Table 2-4. The following modifications will be recommended to the long-term monitoring and operations and maintenance approach:

- Institutional Controls – For properties currently under the control of PSC, the following institutional controls (deed restrictions) will be implemented:
  - Prohibit construction without installation of a VI mitigation system and/or removal or treatment of contamination in groundwater/soil.
  - Notify future building occupants of the existing conditions.
  - Regularly monitor/inspect VI mitigation systems, and other appropriate engineering controls, in order to ensure that they are maintained and operating correctly. This includes inspecting the VI mitigation system to ensure that system exhaust is not being routed into indoor spaces – due to building remodeling/construction.

3.1.5 Tier 5 – Termination of VI Mitigation

The VIAM approach incorporates a new tier (i.e., Tier 5) that was not part of the IPIM approach. Tier 5 provides a process for determining whether or not to VI mitigation systems that have been installed can be shutdown and potentially removed. Tier 5 includes a three-step decision process, presented in Figure 3-2 and summarized below:

Step 1 – Identify Candidate Buildings for SSDS or SMDS Removal: Once a year, buildings that are potential candidates for removal of SSDS or SMDS will be identified based on the most recent four rounds of groundwater data collected in the SWFS Area. The groundwater data from individual water table wells will be compared with residential-based VIRLs on a well-by-well basis. COPC-specific exceedance factors (CCEFs and NCCEFs) will be calculated based on the groundwater data per Tier 1 of the VIAM.

Decision Criteria: Buildings with SSDS or SMDS that are located proximate (i.e., within a 250 foot radius upgradient and downgradient and a 100 foot radius cross-gradient) to wells that have CCEFs less than or equal to 1 (i.e., an excess cancer risk of 1E-06) and NCCEFs less than or equal to 10 (i.e., a hazard index of 1) will be identified as candidates for shutdown of the SSDS or SMDS. These buildings will proceed to Step 2.

Step 2 – Perform Building-Specific Confirmation Groundwater Sampling on Candidate Buildings Identified in Step 1: A minimum of two groundwater samples will be collected (e.g., immediately upgradient and downgradient of the building) from the water table as close as feasible at each candidate building to determine whether or not the concentrations of VOCs in groundwater are high enough to result in indoor air concentrations that exceed Ecology's health benchmarks. COPC-specific exceedance factors (CCEFs and NCCEFs) will be calculated based on the building-specific groundwater data per the approach presented in Tier 1 of the VIAM.

Decision Criteria: Following building-specific groundwater sampling, the SSDS or SMDS in buildings that have groundwater-based CCEFs less than or equal to 1 and NCCEFs less than or equal to 10 will be recommended to Ecology as no longer requiring VI mitigation. Note: All other buildings will be re-evaluated using the Tier 5 methodology when additional groundwater data becomes available.

Step 3 – Confirmation with Ecology and System Termination: PSC and Ecology will implement VI mitigation system termination as follows:

- If the buildings currently have SSDS or SMDS operating, PSC will propose that the building owners and tenants be notified that the system no longer needs to be operated. PSC will also propose that PSC's responsibility for performance monitoring and maintenance/repair of the systems be terminated.

- Once Ecology approves the technical basis for shutting down a particular building's VI mitigation system, an approval letter will be sent to PSC, the building owner, and the building tenant. PSC will then contact the owner and tenant (by phone and mail), explain that the system may now be turned off, clarify that PSC will no longer service or maintain the system, and offer to remove the system. An access agreement will be drafted by PSC and sent to the building owner. The draft agreement will state what actions PSC will take and what condition the building will be left in, following system removal. For those owners who prefer that their systems remain in place, PSC will request that they sign some form of waiver, limiting PSC's future liability. This information will be communicated to Ecology. Once systems are shut down, the procedure outlined in Step 2 would be followed.

3.1.6 Non-PSC Sources Impacting Groundwater in the Georgetown Community

Due to the potential for unidentified sources impacting groundwater located within the SWFS area, PSC may conduct site specific evaluations of potential sources on an as-needed basis to identify suspected locations. In the event that a source is identified, PSC and Ecology will coordinate the transfer of VIAM responsibilities to the appropriate PLP(s) and modify the applicable Tier 1, Tier 2 and Tier 3 activities to reflect the presence of non-PSC source(s).

3.2 EVALUATION OF THE VIAM APPROACH AS A COMPONENT OF THE FINAL CLEANUP REMEDY FOR THE SITE UNDER MTCA

In defining the Final Cleanup Remedy for a site, selection of cleanup actions must account for the minimum requirements outlined in WAC 173-340-360 (2). The Final Cleanup Remedy may involve the use of several cleanup action components of which VIAM is one such component. Other components of the Final Cleanup Remedy will be described in supporting SWFS Technical Memoranda 4, Technology Identification and Screening and SWFS Technical Memoranda 5, Remedial Alternative Development and Evaluation, required to complete the SWFS. This section presents the minimum threshold and other requirements presented in WAC 173-340-460 (2) and shows whether or not the VIAM component of the Final Cleanup Remedy addresses each of the requirements.

(a) **Threshold requirements.** The cleanup action shall:

i. **Protect human health and the environment –** VIAM is an element of the Final Cleanup Remedy that is designed to be protective of indoor air quality. The VIRLs developed for groundwater and indoor air are protective of the inhalation pathway. Individual VIRLs for both residential and commercial scenarios were calculated based on cancer risk and noncancer hazard goals for residents and commercial/industrial workers of 1E-06 and HQ of 0.1, respectively. Tier 1, 2 and 3 determinations are based on a cumulative cancer risk threshold of 1E-05 and/or a hazard index of 1 as the trigger to proceed to Tier 4 (i.e., installation of a VI mitigation system), which is consistent with cumulative risk goals stipulated in MTCA Method B (WAC 173-340-705 (5)) and MTCA Method C (WAC 173-340-706 (5)).

ii. **Comply with cleanup standards –** The VIAM approach, when used in conjunction with source control (i.e., the HCIM) and other remedial measures (e.g., monitored natural attenuation), is expected to comply with the cleanup standards identified in the SWFS. The tiered VIAM approach will continue to be implemented in the SWFS Area until PSC demonstrates compliance with cleanup standards, based on protection of indoor air, for the site established under MTCA (WAC 173-340-700). Groundwater cleanup standards for the SWFS are presented in SWFS Tech Memo 1 (Geomatrix, 2006).

iii. **Comply with applicable state and federal laws –** The VIAM approach, in conjunction with other remedial measures, is designed to comply with the applicable local, state, and federal laws, as discussed in WAC 173-340-710.

iv. **Provide for compliance monitoring –** As part of the VIAM approach, monitoring and regularly scheduled inspections will be performed to confirm that the VI mitigation systems are still functioning as designed. In addition, the results of quarterly groundwater monitoring will be evaluated using the tiered VIAM approach to determine if there are additional buildings where Tier 3, site-specific sampling should be performed and consequently, if VI mitigation systems should be installed (i.e., Tier 4). Compliance monitoring associated with VIAM activities will continue until PSC demonstrates compliance with cleanup standards, based on protection of indoor air, for the site established under MTCA (WAC 173-340-700).

(b) **Other Requirements.** When selecting from action alternatives that fulfill the threshold requirements, the selected action shall:

i. **Use permanent solutions to the maximum extent practicable –** VI mitigation is not a permanent solution and does not address the source (i.e., VOCs in groundwater and/or soil). Permanent solutions for source control and cleanup actions will be discussed in SWFS Technical Memoranda 4 and 5.

ii. **Provide for a reasonable restoration time frame –** Factors to consider when determining whether or not a cleanup action provides for a reasonable time frame include potential risks to human health and the environment. The VIAM approach helps the overall cleanup remedy provide for a reasonable restoration time frame by protecting building occupants during the process of attaining groundwater cleanup standards (WAC 173-340-360(4) (b)).

iii. **Consider public concerns –** The VIAM approach addresses public concerns associated with indoor air. PSC has planned for, and engaged in, public participation and education to address public concerns throughout the IPIM process and will continue to do so during and after the Final Cleanup Remedy for the site has been implemented.

3.3 EVALUATION OF THE VIAM APPROACH RELATIVE TO CURRENT VI GUIDANCE

The VIAM approach presented in this memorandum is generally consistent with the following federal and state guidance:

- California Regional Water Quality Control Board. Screening for Environmental Concerns at Sites with Contaminated Soil and Groundwater. Interim Final. February 2005.

- California Department of Toxic Substances Control. Vapor Intrusion Guidance Document – Final Interim. DTSC/California EPA. December 15, 2004.

- Massachusetts Department of Environmental Protection. Guidelines for the Design, Installation, and Operation of Sub-Slab Depressurization Systems, December 1995.

- New Jersey Department of Environmental Protection. Vapor Intrusion Guidance. October 2005. http://www.nj.gov/dep/srp/guidance/vaporintrusion/.

- New York State Department of Health. Guidance for evaluating Soil Vapor Intrusion in The State of New York. Public Comment Draft. Prepared for New York State Department of Health. February 2005.

- U.S. Environmental Protection Agency. Radon Reduction Techniques for Existing Detached Houses. Technical Guidance (Third Edition) for Active Soil Depressurization Systems. EPA/625/R-93//011. October 1993.

- U.S. Environmental Protection Agency. Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry. Office of Health and Environmental Assessment. Washington, D.C. EPA/600/8-90/066F.

- U.S. Environmental Protection Agency. Radon Mitigation Standards. EPA 402-R-93-078, Revised April 1994.

- U.S. Environmental Protection Agency. Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway. Office of Solid Waste and Emergency Response. Washington, D.C. EPA530-F-02-052. http://www.epa.gov/correctiveaction/eis/vapor.htm.

The guidance documents reviewed typically recommend a tiered approach evolving from conservative screening criteria to increasingly detailed site-specific analyses of the VI pathway.

The tiered VIAM approach is generally consistent with the step-wise approach recommended in the guidance documents as follows:

- The USEPA Office of Solid Waste and Emergency Response (OSWER) Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway (USEPA Draft VI Guidance) recommends comparing site groundwater or soil gas data first with generic risk-based screening concentrations calculated using the JEM (Johnson and Ettinger, 1991; EQM, 2003). The JEM has been modified to incorporate the default values recommended in Appendix G of the USEPA Draft VI Guidance (USEPA, 2002).

- NJDEP employs generic screening levels for groundwater, indoor air and sub-slab and recommends groundwater as the first medium to be investigated for the VI pathway (NJDEP, 2005). No further investigation is required if appropriate groundwater data are less than the NJDEP groundwater screening levels. Near slab or sub-slab soil gas sampling is recommended if the groundwater data exceed NJDEP groundwater screening levels.

- The California Regional Water Quality Board (CRWQB) recommends the sequential collection and evaluation of groundwater and soil gas data prior to collecting indoor air. CRWQB provides groundwater screening levels that are protective of potential VI concerns and further uses the JEM to differentiate between site-specific conditions with high permeability vadose zone soil versus low permeability vadose zone soil (CRWQCB, 2005). Screening criteria are developed using the JEM with California toxicity factors. Methods used to develop the screening levels are similar to those used by the California Office of Environmental Health Hazard Assessment to develop soil gas screening levels for VI concerns and recommended by California Department of Toxic Substances Control (DTSC) (DTSC, 2004). Soil gas samples are recommended for sites where groundwater screening levels for VI are approached or exceeded.

The DTSC and NYSDOH approaches differ from the VIAM approach as follows:

- The DTSC VI guidance recommends using soil gas measurements as the primary screen to evaluate VI because soil gas data represent a direct measurement of the contaminant that will migrate into indoor air. DTSC provides default attenuation factors for existing and future slab-on-grade, crawl space, and basement residential scenarios as well as existing and future commercial scenarios (DTSC, 2004). Even at locations where groundwater is the source medium, the groundwater evaluation is secondary to soil gas. However, the USEPA JEM spreadsheets, as modified by DTSC, are available for site-specific VI evaluations of groundwater and soil gas.

- NYSDOH recommends soil vapor and/or sub-slab samples, indoor air, and outdoor air samples to investigate the VI pathway. NYSDOH currently does not have any standards, criteria, or guidance values for concentrations of constituents in subsurface vapors or groundwater that are protective of indoor air (NYSDOH, 2005). Hence, the NYSDOH does not use subsurface information to rule out the need for additional sampling or addressing exposures at nearby buildings. The NYSDOH Draft VI guidance provides a decision matrix that relies on sub-slab, indoor and ambient air (NYSDOH, 2005). This decision matrix is discussed in comparison to Tier 3 of the PSC tiered approach (see Section 3.3.2).

3.3.1 Tier 1 and Tier 2 of the VIAM Approach – Consistency with Current Guidance

Use of the Groundwater Screening Step

Tier 1 and Tier 2 determinations are based on a groundwater screening step that is very appropriate for the site. The water table is relatively shallow and well characterized. Groundwater data are current, readily available, and updated quarterly so that locations are continuously assessed to determine whether the building should be evaluated under Tier 3 or Tier 4. The use of groundwater concentrations to identify buildings with potential VI concerns is consistent with the majority of federal and state guidance documents (USEPA, 2002; NJDEP, 2005; CRWQCB, 2005). However, there are some VI guidance documents that do not recommend this approach (DTSC, 2004; NYSDOH, 2005). As presented in the previous section, DTSC primarily recommends the evaluation of soil gas data and NYSDOH relies primarily on a decision matrix based on concurrent sub-slab soil gas, indoor air, and ambient air data.

3.3.2 Tier 3 of the VIAM Approach – Consistency with Current VI Guidance

Tier 3 of the VIAM approach includes the key steps that are recommended in State and Federal guidance when performing a site-specific VI evaluation, including thorough building surveys and co-located, site-specific groundwater, sub-slab soil gas, indoor air, and ambient air sampling. However, there are two elements in Tier 3 of the VIAM approach that warrant further discussion with regards to State and Federal guidance and state-of the science:

1. Accounting for the contribution of background sources of VOCs to measured indoor air concentrations; and

2. Seasonal variations and their impact on site-specific sampling.

Accounting for the Contribution of Background Sources of VOCs to Measured Indoor Air Concentrations

When evaluating site-specific data collected under Tier 3 of the VIAM approach, measured indoor air concentrations are corrected by subtracting the maximum detected ambient (outdoor) air concentration (measured during the sampling event) from the maximum detected indoor air concentration to quantify the contribution of VOCs that are present due to background[13]. This methodology is based on a practical approach that transparently and quickly assesses the risks associated with VI. However, this is just one component of the weight-of-evidence evaluation that is used in Tier 3 of the VIAM approach to quantify the concentration of VOCs measured in indoor air that are associated with VI. Other components of the weight-of-evidence evaluation include the results of the building survey, presence or absence of the VOC in groundwater/soil gas, and comparability to historical data from the location (if available).

Federal, state, and regional VI guidance documents agree that an assessment of background is critical to focus the VI pathway evaluation on VOCs that are related to the source (i.e., impacted groundwater, soil, or soil gas). However, the specific methodology for quantifying the contribution of VOCs that are present due to background sources (e.g., building materials, human activity patterns, and ambient air) is not well developed and/or clearly articulated in current VI guidance.

Nonetheless, most VI guidance documents recommend the use of multiple lines of evidence to assess background sources in indoor air but stop short of recommending specific criteria or a "mathematical equation" to quantify the contribution of background. For example:

- USEPA recommends that "vapors attributable to background be accounted for during the site-specific assessment." (USEPA, 2002) Appendix I of the USEPA Draft VI Guidance recommends "collecting a contemporaneous ambient (outdoor) air sample to be used in comparison to indoor concentrations and aid in characterizing possible background contribution from ambient (outdoor air)" (USEPA, 2002).

- NJDEP proposes an approach that is designed to be "a professional judgment based on a progression of empirical facts, some more relevant than others" (NJDEP, 2005). The guidance states that "by comparing the site-specific contaminants of concern detected in soil gas samples with indoor air and ambient air results, the investigator can validate the designation of background contaminants and thus limit any remedial action" (NJDEP, 2005). NJDEP also states that, in general, mitigation will not be required if site-specific ambient air results are in excess of indoor air results.

- California DTSC recommends collecting background samples to help focus assessment and mitigation on target constituents associated with the source, but states that background data should be included and discussed qualitatively in the uncertainty section (DTSC, 2004).

[13] The original IPIM approach adjusted indoor air sampling results using the maximum concentration from constituents detected in ambient air and concentrations from peer-reviewed national background indoor air sources (the lower of the median or mean of the 25th and 75th percentiles). At Ecology's request, the current IPIM approach (and proposed approach) adjusts indoor air concentrations for background using only concentrations measured in co-located outdoor air.

In contrast, the State of New York has more specific criteria for integrating background into the VI assessment and mitigation approach (NYSDOH, 2005). The NYSDOH Draft VI Guidance recommends simultaneous ambient air sampling with all indoor air sampling to evaluate the extent to which ambient sources are influencing indoor air quality. They also recommend background sampling during soil gas sampling events to evaluate background that may be infiltrating into soil vapor sampling apparatus (NYSDOH, 2005). The NYSDOH Draft VI Guidance (NYSDOH, 2005) provides a summary table of "background levels to be used as screening tools when determining appropriate actions to address exposure." These levels are derived from several studies, conducted both nationally and in the State of New York. In addition, the NYSDOH has developed several guidelines for VOCs in air to address specific background situations, including guidelines for methylene chloride (60 micrograms per cubic meter [ug/m^3]), tetrachloroethylene (100 ug/m^3) and trichloroethene (5 ug/m^3) (NYSDOH, 2005). These background criteria are built into decision matrices for evaluation of indoor air and sub-slab data to determine future actions (e.g., continued monitoring or mitigation).

Tier 3 of the VIAM approach is consistent with the NYSDOH Draft VI Guidance (NYSDOH, 2005) in that specific values, representing background concentrations, are used to quantify background concentrations. However, while subtracting ambient air measurements from indoor air measurements before comparing the result to a risk-based concentration is a definitive way to isolate the ambient air component, its consistency with current VI guidance documents cannot be determined – because virtually all VI guidance documents do not present a specific approach for quantifying the contribution from background sources.

To address some of Ecology's concerns with this approach, the uncertainties associated with correcting for background using ambient air data versus not correcting for background are summarized in Section 4.2 and presented in Appendix B.

To support the correction for background, the Tier 3 VIAM approach includes additional lines of evidence that are consistently recommended in federal and state guidance (NJDEP, 2005; NYSDOH, 2005; DTSC, 2004) including:

- Using a tiered, sequential approach and working with a well characterized/delineated groundwater plume (or subsurface contamination) to help limit the scope of the site-specific investigation.

- Performing a comprehensive site visit and building evaluation in advance of the indoor air sampling event to identify and minimize the impact of background indoor air sources.

- Co-located and contemporaneous sampling of indoor air, ambient air, sub-slab air and groundwater to help identify target VOCs and limit the scope and complexity of the VI investigation and associated background assessment.

- Using sub-slab samples to confirm the presence or absence of target VOCs in indoor air and to help determine the need for further actions.

Seasonal Variations and their Impact on Site-Specific Sampling

Under the IPIM program, described in Section 2, Ecology required that site-specific sampling be performed as soon as a location was identified for Tier 3 and the Tier 3 site-specific work plan was approved. However, most VI guidance documents recommend collecting indoor air samples during the heating season (i.e., November through March) when windows and doors remain closed and the building is being heated. This is often cited as one of the "worst-case" conditions for VI because of building "stack effects" whereby VI can potentially occur at a higher rate. However, these "stack effects" are typically more pronounced in colder climates where the ground temperature changes more significantly than in the Pacific Northwest. Nonetheless, based on comments from Ecology and the recommendations presented in current VI guidance documents, Tier 3 under the VIAM approach was modified to only collect samples during the heating season from November through March.

3.3.3 Tier 4 of the VIAM Approach – Consistency with Current VI Guidance

Tier 4 of the VIAM approach is consistent with current VI Guidance and Radon Mitigation Guidance documents (USEPA, 1993; USEPA, 1994b; USEPA, 2002).

VI Mitigation System Design and Installation

The use of SSDS to effectively mitigate homes with elevated radon gas levels is well established, and performance data indicate that radon concentrations can be reduced by 90 to 95 percent (USEPA, 1993). The effectiveness of this approach for reducing VOCs was confirmed by a study done in Colorado (Folkes, 2003; Folkes and Kurz, 2002). In this study, 301 SSDS, SMDS, or combined systems, were installed to mitigate 1,1-dichloroethene (1,1-DCE). Concentrations of 1,1-DCE were reduced by up to three orders of magnitude to concentrations below the Colorado interim action level of 0.49 ug/m^3. In most cases, standard systems (i.e., with one suction point, a standard-size suction pit, and a 90-watt fan) were installed generally following the USEPA guidelines for radon mitigation (USEPA 1993). Minor modifications to the systems were required at 30 percent of the homes in order to meet interim action levels. Modifications to the SSDS included enlarging the suction pit, adding suction pits, and/or replacing the 90-watt fan with a 150-watt fan. Some of the SMDS were modified by sealing small gaps between the liner and foundation wall, adding more perforated pipe to extend the suction field under the liner, and installing a 150-watt fan in place of a 90-watt fan.

VI Mitigation System Verification

Tier 4 of the VIAM approach requires a process for verifying that the SSDS/ SMDS are reducing the levels of VOCs in indoor air, associated with migration from groundwater, below levels of concern to human health as established by Ecology.

The primary method for verifying system effectiveness for SSDS is to ensure that a negative pressure differential of at least one Pa is achieved across the extent of the slab[14]. For systems installed to date, the manometer readings collected right above the sub-slab sump systems, immediately after installation, ranged from 480 to 560 Pa, which was well above the minimum (249 Pa) according to guidelines for

[14] This pressure differential has been shown to be effective in radon mitigation projects, and is below the five Pa pressure differential that, according to EPA (USEPA, 1994b), can lead to backdrafting.

radon mitigation (USEPA, 1993). This performance standard is used routinely within the radon industry and has been proven effective at reducing radon levels to below regulatory action levels (PSC, 2003b, 2005a). This performance standard is also consistent with Massachusetts Department of Environmental Protection (MADEP), NJDEP and NYSDOH guidelines (MADEP, 1995; NJDEP, 2005; NYSDOH, 2005), which state that the primary performance standard for confirming effective SSDS operation is through demonstrating that a negative pressure field extends under the entire slab.

For crawl space SMDS, it is not possible to measure the extent of the negative pressure field. However, additional perforated pipe beneath the membrane serves to extend the suction field beneath the liner and to increase airflow and movement of VOCs into the pipes and out of the subsurface. The primary way to measure the effectiveness of an SMDS is through inspection of the manometer installed on the exhaust pipe. For systems installed to date, manometer readings taken right above the sub-membrane systems at installation ranged from 220 to 360 Pa, which was within the guidelines for radon mitigation (USEPA, 1993). The large volume of air being exhausted from under the membranes (110 to 180 cubic feet per minute [cfm]) provided further indication that crawl space areas were being sufficiently ventilated.

Media Transfer

Ecology has commented on the potential for VI mitigation to contaminate ambient air "to an unacceptable degree" and has requested that this potential for media transfer be factored into the SWFS decisions for protection of human health. At Ecology's request, PSC performed a screening-level dispersion analysis of emissions from three VI mitigation sources at the Georgetown site (PTC, 2005b). This included two sources of emissions from building VI mitigation stacks and exhaust from the granular activated carbon beds associated with the groundwater treatment stack (air stripper) that is part of the HCIM. Stack exhaust concentrations were measured from two sources, but VOC concentrations in sub-slab soil gas were used as the mitigation exhaust gas in one of the building sources. Maximum concentrations were used to calculate the emission rates and an air quality analysis using the Industrial Source Complex Short Term Version 3 (ISCST3) model was performed to determine the air quality impact of the emission sources. The predicted peak annual average ambient air concentrations were well below the MTCA Method B and MTCA Method C air cleanup levels for all VOCs.

Post-VI Mitigation System Installation Confirmation Sampling

The Tier 4 VIAM approach includes VOC sampling for a subset of buildings to provide additional verification that the established pressure differentials (discussed above) are adequate for VOC mitigation. Confirmation sampling is performed in representative buildings with basement/slab-on-grade construction and buildings with crawl spaces.

This is consistent with both NYSDOH and NJDEP VI Guidance, which recommend confirmation indoor air sampling after system installation to verify the effectiveness of the system (NJDEP, 2005; NYSDOH, 2005). NYSDOH recommends post-mitigation sampling targeted at buildings where pre-mitigation samples were collected and where physical data or building construction suggest "possible impediments to comprehensive sub-slab communication of the depressurization system (i.e., locations with wet or oily sub-slab soils, multiple foundations and footings, minimal pressure differentials between the interior and sub-slab)" (NYSDOH, 2005). In cases of widespread mitigation, similar to the Georgetown site, NYSDOH recommends sampling a representative number of buildings (NYSDOH, 2005).

Note: While NYSDOH recommends post-installation sampling, the guidance also states: "Generally, air monitoring is not required if the system has been installed properly and is maintaining a vacuum beneath the entire slab" (NYSDOH, 2005).

Public Relations and Community Outreach

PSC is concerned about the health and welfare of its neighbors in the Georgetown community and has worked with Ecology to keep the community informed of the status of the cleanup at the PSC Georgetown facility and the on-going VI investigation/mitigation work. Most of the VI mitigation systems are installed on properties not owned by PSC. Efforts made by PSC to keep the public informed are consistent with federal and state guidance and include the following:

- Providing each building occupant an information package to facilitate their understanding of the VI mitigation system's operation, maintenance and monitoring.
- Maintaining and updating a site contact list containing names, addresses and telephone numbers of individuals and organizations with interest or involvement in the site.
- Providing Georgetown neighbors and interested parties a summary of contact information for staff working on the site.
- Holding community information meetings and providing Fact Sheets that summarize important information about the site.
- Informing building occupants through transmittal letters that provide the sampling results and conclusions drawn from the data when indoor air and/or sub-slab vapor samples are collected from within or beneath their building.
- Emphasizing personal contact with neighbors through site-visits and follow-up visits.
- Providing a document repository of all investigations performed to date.

3.3.4 Tier 5 of the VIAM Approach – Consistency with Current VI Guidance

Termination of VI Mitigation System Operations

Both NYSDOH and NJDEP VI Guidance provide guidelines for determining whether a mitigation system may be turned off. This determination is based on several factors including concentrations of VOCs in subsurface sources (i.e., groundwater concentrations are below VIRLs) and indoor air quality after systems are turned off.

- NJDEP states that once the VI pathway is no longer complete, a proposal may be submitted to NJDEP to cease operation. Upon approval from NJDEP for system termination, samples of indoor air and sub-slab soil gas should be collected. Sampling should occur during winter and early spring (November through March). The results of sampling should be submitted in a Remedial Action Progress Report and subsequent sampling rounds may be required based on

NJDEP review. Analytical parameters should include the COPCs analyzed during the initial startup of the VI mitigation system (NJDEP, 2005). No specific analytical criteria are provided for termination sampling, but verification samples for indoor air are compared with NJDEP's Indoor Air Screening Levels (with consideration for background sources) (NJDEP, 2005).

- NYSDOH also requires approval from the State priory to removal of the VI mitigation system. The determination that VI mitigation is no longer needed considers several factors, including:

1. Confirmation that the subsurface source (e.g., groundwater, soil) has been remediated;
2. Confirmation that residual contamination in subsurface vapors is not affecting indoor air quality (based on soil vapor and/or sub-slab sampling results);
3. Confirmation that residual contamination is not affecting indoor air quality after the VI system is turned off (based on indoor air, outdoor air and sub-slab vapor sampling results at a representative number of buildings); and
4. Confirmation that there is no "rebound" effect after a period of time, which may require additional sampling events, to be determined on a site-specific basis.

Although NJDEP and NYSDOH provide no specific analytical criteria for termination sampling, their approach is generally consistent with the VIAM approach for Tier 5.

SECTION 4 – UNCERTAINTY ANALYSIS

This section evaluates key uncertainties associated with the VIAM approach. Key uncertainties were identified as components of the VIAM approach that may have a significant probability of resulting in false positive decision errors (i.e., sites identified as requiring VI mitigation do not actually need mitigation) or false negative decision errors (i.e., sites identified as not requiring VI mitigation actually need mitigation). The key uncertainties addressed in this section are summarized below:

- Development of VIRLs. Specifically:
    - The use of a provisional cancer slope factor for trichloroethylene (TCE), which is one of the primary risk drivers for the site.
    - The use of empirically-derived GIVFs versus GIVFs developed using the JEM to calculate COPC-specific VIRLs.
- Tier 3 of the VIAM Approach – Quantifying the contribution of background ambient air concentrations to measured indoor air concentrations.

4.1 DEVELOPMENT OF VAPOR INTRUSION REMEDIATION LEVELS

The most significant sources of uncertainty related to the development of VIRLs are discussed below.

4.1.1 Using a Provisional Slope Factor to Develop VIRLs for TCE

TCE is a primary risk driver for the Georgetown site. The provisional cancer slope factor used for developing the VIRL for TCE is uncertain and may result in an overestimation of the risks to human health from the inhalation pathway. In the Draft Risk Assessment (PSC, 2001), a provisional USEPA inhalation slope factor of 0.006 mg/kg-day^{-1} was used for TCE to evaluate risks. In August 2001, the USEPA's National Center for Environmental Assessment (NCEA) released the *Preliminary Draft Trichloroethylene Health Risk Assessment: Synthesis and Characterization (THRA)* (USEPA, 2001). This document proposed a range of slope factors for TCE of 0.02 to 0.4 mg/kg-day^{-1}. As required by Ecology, the 0.4 mg/kg-day^{-1} slope factor was used to develop VIRLs for indoor air and groundwater. This value is at the high end of the range of slope factors presented in the THRA, and is over 66 times higher than the provisional USEPA slope factor used in the Draft HHERA (PSC, 2001).

IPIM Tech Memo 1 presented a comparison of residential CCEFs calculated using the 0.006 and 0.4 mg/kg-day^{-1} slope factors for TCE (PSC, 2003a). All parameters used to calculate the CCEFs were identical except for the slope factor for TCE. This analysis showed that using the provisional slope factor of 0.4 for TCE has a significant impact on the results. When using a slope factor of 0.4 mg/kg-day^{-1}, 192 addresses at 63 buildings were potential candidates for Tier 3. However, when the 0.006 mg/kg-day^{-1} slope factor was used, only 136 addresses at 34 buildings were potential candidates for Tier 3.

Both slope factors are highly uncertain, as is evidenced by the fact that the values are not on Integrated Risk Information System (IRIS), and therefore do not represent USEPA consensus values. The primary area of uncertainty associated with using the 0.4 mg/kg-day^{-1} slope factor for inhalation exposures is that it is based on a route-to-route extrapolation from an oral drinking water study in which USEPA assumed 100 percent absorption efficiency. This is contrary to the USEPA Guidance *Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry* (USEPA, 1994a), which states, "Regardless of the toxic endpoint being considered, a minimum of information is required to construct the plausible dosimetry for the routes of interest. This information includes both the nature of the toxic effect and a description of the relationship between exposure and toxic effect." This information is needed to determine the "absorbed dose" for each route of exposure so that the appropriate route-to-route extrapolation can be made. The THRA recognized this uncertainty by stating, "Route extrapolations can differ by 25-fold, depending on whether internal trichloroacetic acid or dichloroacetic acid is used as the dose metric. Further research could identify the appropriate internal dose metric for each toxic effect."

The use of a provisional value for TCE (i.e., 0.4 mg/kg day-1) may result in a more stringent VIRL for this risk-driving constituent, which has the effect of biasing decision making toward VI mitigation where mitigation may not be necessary (as opposed to not taking measures when they should be taken).

4.1.2 Use of Empirical Data to Develop GIVFs for Calculating VIRLs Rather than Using GIVFs Predicted by the JEM

Groundwater VIRLs were calculated using COPC-specific GIVFs that estimate an indoor air concentration based on the concentration in groundwater. GIVFs were derived using empirical data, as described in IPIM Tech Memo 1 (PSC, 2003a), using a conservative approach to ensure that the resulting IPIMALs would err towards being more protective rather than less protective. The empirical data resulted in a fairly wide range of GIVFs for specific TCs, which was likely an artifact of background sources, heterogeneity in the subsurface, and varying building characteristics. Furthermore, the combined effect of calculating GIVFs from non-detected indoor air (reported at the method reporting limit or higher) and low groundwater concentrations, commonly resulted in GIVFs that appeared to be biased high (i.e., predicting more VI rather than less VI). A thorough review process was conducted to ensure that the most conservative TC-specific and building-specific GIVF was selected to calculate GIVFs for non-TC constituents. Because the most conservative GIVF (i.e., that representing maximum migration to indoor air) was selected for use in developing IPIMALs, it is likely that the GIVFs over-estimate migration potential and subsequently, IPIMALs err toward being more protective rather than less protective.

During the process of developing the GIVFs (PSC, 2003a), uncertainties were tested by comparing the empirical data to a range of concentrations predicted by the JEM. The results provided a strong weight-of-evidence that vapor migration to indoor air at the site is occurring through loamy sand with relatively high moisture content (PSC, 2003a). Appendix A presents further analysis of these uncertainties using the most current version of the JEM[15] and standard default building-related parameters[16]. The VIAM

[15] USEPA spreadsheet GW-Adv-04.xls (http://risk.lsd.ornl.gov/johnson_ettinger.html) was used for this evaluation.

VIRLs (calculated using the same empirically-derived GIVFs used to develop IPIMALs) were compared to action levels calculated using GIVFs predicted by the JEM for two sub-surface scenarios: 1) loamy sand (site-specific) and 2) sand (conservative).

Action levels calculated using the JEM Loamy Sand scenario are very close to the VIAM VIRLs calculated using the empirically-derived GIVFs. When applied to the IPIM Decision Tree (Tier 1 & Tier 2), the JEM Loamy Sand action levels result in no appreciable increase in the Tier 1 or Tier 2 footprints (predicted by using the proposed VIRLs) and no additional buildings were identified for further evaluation under Tier 3. When action levels, calculated using the JEM Sand scenario, were applied to Tier 1 and Tier 2, the Tier 1 and Tier 2 footprints (predicted by using the proposed VIRLs) slightly increased in size. Ten additional buildings (three residential, six commercial and one with an unverified land use) fell within the footprint, which is an increase of approximately nine percent.

The close comparison of the proposed VIRLs with the JEM Loamy Sand action levels reaffirms that the proposed VIRLs are based on a reasonable approach for predicting migration of VOCs to indoor air. It is unlikely that the most conservative scenario predicted by the JEM Sand scenario represents conditions at the site. However, even when using this highly conservative scenario, only 10 more Tier 3 buildings were identified as moving to Tier 3. Furthermore, the JEM assumes standard default building-related parameters for residential buildings, which do not represent conditions in commercial buildings. For example, a conservative indoor air mixing rate of 0.25/hr was assumed in the JEM and this likely underestimates the extent of mixing that is occurring in most commercial buildings because of the Heating, Ventilation, and Air Conditioning (HVAC) systems which actually pump "make-up" air from outside the building into the building. The NJDEP VI Guidance notes that HVAC systems that generate positive air pressure can reasonably be expected to prevent or minimize VI with the structure (below levels normally calculated using attenuation factors in the JEM (NJDEP, 2005).

In summary, action levels calculated using the JEM and site-specific conditions (loamy sand) are comparable with the proposed VIRLs that were calculated using the GIVFs developed with empirical data. Conservative assumptions built into both the empirical and JEM-based approach are likely to result in more stringent VIRLs that would have the effect of biasing decisions toward VI mitigation (as opposed to not taking measures when they should be taken). VIRLs calculated using the JEM Sand scenario are more conservative and would result in additional buildings being moved to Tier 3.

4.2 TIER 3 OF THE VIAM APPROACH – QUANTIFYING THE CONTRIBUTION OF BACKGROUND AMBIENT AIR CONCENTRATIONS TO MEASURED INDOOR AIR CONCENTRATIONS

The primary uncertainty associated with Tier 3 of the VIAM decision tree is the influence of background sources, which may mask the concentrations of VOCs associated with VI. Background concentrations are influenced by both indoor air sources and contamination in ambient air. Background indoor air sampling is typically not recommended, primarily because site-specific background indoor air samples cannot be collected from a building that may be impacted from subsurface VI. Therefore, sampling must occur from "control" buildings (i.e., buildings constructed of similar materials, having similar layouts, and in an

[16] Standard default parameters based on USEPA VI Guidance (USEPA, 2002) , basement scenario and depth to groundwater of 10 feet below ground surface.

area with similar ambient air background conditions). These "control" buildings must be located in an area where VOCs are not detected in the subsurface (i.e., soil, groundwater or soil gas). Because background sampling of indoor air from "control" buildings is not considered a feasible approach for most sites, some agencies recommend that literature values be selected to represent background concentrations in indoor air, in addition to site-specific measurements in ambient air.

Literature values for background concentrations of VOCs in indoor air have been reported in local, regional, national and international studies. Appendix F of the NJDEP VI Guidance presents a summary of available literature studies through June 2002 that were conducted primarily in urban areas throughout the United States and focused on background levels of VOCs in homes and other structures (NJDEP, 2005). Fifty-two VOCs were included in the summary. The guidance suggests that comparison with literature values is most practical for commonly-occurring and frequently-studied VOCs (i.e., benzene, carbon tetrachloride, chloroform, p-dichlorobenzene, ethylbenzene, styrene, tetrachloroethene (PCE), 1,1,1-trichloroethane, TCE, toluene, and xylene).

The USEPA is continuously expanding the VI database of published or otherwise documented background indoor air data in order to identify studies with data sets of known and acceptable quality for the VI database (RTI, 2003). The results of these studies highlight the difficulties of distinguishing background indoor air from VI sources, particularly for those COPCs with risk-based action levels that are one or two orders of magnitude below the median background indoor air concentration indicated by these studies. A comparison of literature values for measured background indoor air levels with regional risk-based limits is shown in Table 4-1 for TCE and PCE.

The original IPIM approach recommended using the lower of the selected literature value, or the value measured in ambient air, for correcting indoor air values. This approach was later modified by Ecology to exclude the use of literature values (Ecology, 2003). The use of ambient air sampling is a valid approach because it provides background concentrations outside of the building being investigated at the time of the indoor air-sampling event. Furthermore, ambient air sampling represents site-specific background concentrations, which can vary significantly over short distances. However, using only ambient air concentrations to represent background may underestimate the true background contribution because it does not include potential contributions from indoor air sources and human activity patterns.

The results of Tier 3 evaluations performed under the IPIM approach (which is almost identical to the VIAM approach) were used to evaluate the impact of correcting measured indoor air concentrations based on background ambient air concentrations. Appendix B presents the results of an analysis that evaluated the impact of comparing corrected indoor air measurements to VIRLs versus comparing uncorrected indoor air measurements to VIRLs. The impact was measured in the number of Tier 3 buildings that would have been moved to Tier 4 under each scenario. To date, a total of 18 Tier 3 locations did not proceed to Tier 4 under the IPIM program after the site-specific VI assessments were completed. In other words, these locations had indoor air concentrations (corrected by subtracting the ambient air concentrations from indoor air concentrations), associated with VI from groundwater, below Ecology's risk threshold and therefore, they did not proceed to Tier 4. These buildings were re-evaluated using uncorrected indoor air concentrations to determine whether or not any of the buildings would be re-classified as requiring VI mitigation (i.e., proceed to Tier 4). Following this re-analysis, the status for 10 of the 18 buildings remained unchanged (i.e., these buildings moved back to Tier 1 and Tier 2 monitoring just as the results the original Tier 3 analysis indicated). Eight buildings (three residential and five commercial) were re-classified as requiring VI mitigation (i.e., proceed to Tier 4). That is, 44 percent of the buildings originally evaluated under Tier 3 and determined not to require VI mitigation would be identified as requiring VI mitigation as the result of not correcting for background by subtracting ambient air concentrations from indoor air concentrations prior to comparing the indoor air concentration to the VIRLs.

A comparison of the maximum detected indoor air concentrations of TCE with modeled indoor air concentrations (i.e., modeled by multiplying the groundwater concentrations by GIVFs) of TCE (which was the primary risk driver at all locations) indicates that the measured indoor air concentrations are most likely not related to VI from groundwater because the measured concentrations are significantly higher than the modeled concentrations at six out of eight of the locations (see Appendix B). One of the eight locations (665 S. Lucile Street) had modeled indoor air concentrations that were higher than the measured indoor concentrations. This is a commercial building and there is more uncertainty associated with the GIVFs as they relate to commercial buildings because the GIVFs are based on empirical data from residential buildings and more likely to over-predict concentrations in indoor air in commercial buildings.

The use of uncorrected indoor air concentrations in Tier 3 would have the effect of biasing decision making toward VI mitigation where mitigation may not be necessary (as opposed to not taking measures when they should be taken). The overall impact of using uncorrected indoor air concentrations in Tier 3 evaluations on resources would potentially be significant because five of the eight buildings that would require VI mitigation systems are commercial buildings. The impact of this change would also be reflected in the uncertainty associated with long-term monitoring because it would be difficult to measure decreasing trends in VI due to elevated background concentrations.

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Table 2-1 – Exposure Parameters Used to Calculate IPIMALs

Parameter	Abbreviation	Units	Restricted – Industrial/Commercial Scenario[1]				Unrestricted – Residential Scenario[1]					
			NonCarcinogen		Carcinogen		NonCarcinogen		Carcinogen			
			Value	Source	Value	Source	Value	Source	Child Value	Source	Adult Value	Source
Air inhalation intake rate	BR	m^3/hr	1.5	USEPA	1.5	USEPA	0.417	Eq. 750-1	0.417	Eq. 750-1	0.833	Eq. 750-2
Exposure time	ET	hr/day	10	USEPA	10	USEPA	24	Eq. 750-1	24	Eq. 750-1	24	Eq. 750-2
Exposure frequency	EXF	day/yr	250	USEPA	250	USEPA	365	Eq. 750-1	365	Eq. 750-2	365	Eq. 750-2
Exposure duration	ED	yr	25	Eq. 745-1	25	Eq. 745-2	6	Eq. 750-1	6	USEPA	24	USEPA
Average body weight	ABW	kg	70	Eq. 745-1	70	Eq. 745-2	16	Eq. 750-1	16	Eq. 750-1	70	Eq. 750-2
Averaging time	AT	day	9125	Eq. 745-1	27375	Eq. 745-2	2190	Eq. 750-1	27375	Eq. 750-2	27375	Eq. 750-2
Unit conversion factor	UCF	ug/mg	1000	--	1000	USEPA	1000	--	1000	--	1000	--
Target risk[2]	Risk	unitless	--	--	1.00E-06	SSRLG	n/a	--	1.00E-06	SSRLG	1.00E-06	SSRLG
Target hazard quotient[2]	THQ	unitless	0.1	SSRLG	--	--	0.1	SSRLG	0.1	--	0.1	--

Notes:
-- = Not applicable.
USEPA = USEPA. 1991. Use of standard default exposure factors. Memo from P. Cirone to Risk Assessors. EPA Region 10, Seattle, WA. April 18, 1991.
Eq. 745-1, Eq. 745-2, Eq. 750-1, and Eq. 750-2 are Equations and Input Parameters defined in MTCA.
MTCA = Model Toxics Control Act Cleanup Regulation Chapter 173-340 WAC Amended February 12, 2001.
SSRLG = Site-Specific Remediation Level Goal.
[1] Exposure parameters defined in Draft HHERA (PSC, 2001). Residential cancer-based IPIMALs were calculated for a child and adult using the following age-integrated equation:
IPIMAL (ug/m^3) = (Risk/(((((adultBR*adultEF)/adultBW)*adultED) + (((childBR*childEF)/childBW)*childED))/AT)*UCF)/ Cancer Slope Factor
[2] Target hazard quotient of 0.1 and target risk of 1E-06 used for used for both scenarios in developing IPIMALs.

Table 2-2 – Indoor Air and Groundwater IPIMALs for Residential and Commercial Scenarios

COPC	Residential Air IPIMAL (ug/m^3)		Commercial Air IPIMAL (ug/m^3)		Residential Groundwater[1] IPIMAL (ug/L)		Commercial Groundwater[1] IPIMAL (ug/L)		Inhalation Reference Dose (mg/kg-day)		Inhalation Slope Factor (mg/kg-day)$^{-1}$	
	Cancer	Noncancer	Cancer	Noncancer	Cancer	Noncancer	Cancer	Noncancer				
1,1,1-trichloroethane	--	1.0E+02	--	4.3E+02	--	1.1E+03	--	4.7E+03	6.3E-01	4	--	9
1,1-dichloroethane	--	2.3E+01	--	9.7E+01	--	7.5E+02	--	3.2E+03	1.4E-01	2	--	9
1,1-dichloroethylene	--	9.1E+00	--	3.9E+01	--	5.3E+01	--	2.3E+02	5.7E-02	3	--	8
1,2,4-trimethylbenzene	--	2.7E-01	--	1.2E+00	--	1.3E+01	--	5.5E+01	1.7E-03	4	--	9
1,2-dichloroethane	7.8E-02	2.2E-01	2.2E-01	9.5E-01	1.0E+01	3.0E+01	3.0E+01	1.3E+02	1.4E-03	4	9.1E-02	3
1,3,5-trimethylbenzene	--	2.7E-01	--	1.2E+00	--	9.8E+00	--	4.2E+01	1.7E-03	4	--	9
2-hexanone	--	8.0E-01	--	3.4E+00	--	6.1E+02	--	2.6E+03	5.0E-03	4	--	9
Benzene	2.6E-01	1.4E+00	7.5E-01	5.8E+00	7.8E+00	4.1E+01	2.2E+01	1.7E+02	8.6E-03	3	2.7E-02	3
Chloroethane	--	4.6E+02	--	1.9E+03	--	5.4E+03	--	2.3E+04	2.9E+00	3	--	9
Chloroform	8.8E-02	2.2E+00	2.5E-01	9.5E+00	3.3E+00	8.5E+01	9.6E+00	3.6E+02	1.4E-02	5	8.1E-02	3
Cis-1,2-dichloroethylene	--	1.6E+00	--	6.8E+00	--	7.3E+01	--	3.1E+02	1.0E-02	6	--	9
Ethylbenzene	--	4.6E+01	--	1.9E+02	--	1.3E+03	--	5.4E+03	2.9E-01	3	--	9
Naphthalene	--	1.4E-01	--	5.8E-01	--	5.9E+01	--	2.5E+02	8.6E-04	3	--	9
P-isopropyltoluene	--	1.8E+01	--	7.8E+01	--	7.5E+01	--	3.2E+02	1.1E-01	6	--	9
Propylbenzene	--	1.6E+00	--	6.8E+00	--	2.7E+01	--	1.1E+02	1.0E-02	6	--	9
Sec-butylbenzene	--	1.6E+00	--	6.8E+00	--	2.3E+01	--	9.9E+01	1.0E-02	6	--	9
Tetrachloroethylene	3.4E-01	2.7E+01	9.7E-01	1.2E+02	4.0E+00	3.3E+02	1.2E+01	1.4E+03	1.7E-01	4	2.1E-02	7
Toluene	--	1.8E+01	--	7.8E+01	--	5.0E+02	--	2.1E+03	1.1E-01	3	--	9
Trans-1,2-dichloroethylene	--	3.2E+00	--	1.4E+01	--	6.5E+01	--	2.8E+02	2.0E-02	6	--	9
Trichloroethylene	2.0E-02	1.6E+00	5.0E-02	6.8E+00	4.0E-01	3.0E+01	9.0E-01	1.3E+02	1.0E-02	4	4.0E-01	4
Vinyl Chloride	2.3E-01	4.6E+00	6.6E-01	1.9E+01	1.0E+00	2.1E+01	3.0E+00	8.8E+01	2.9E-02	3	3.1E-02	3

Notes:
-- = No toxicity value was available. Therefore, an IPIMAL could not be calculated.
The IPMALs presented in this table are based on the Preliminary Remedial Action Levels (PRALs) presented in the HHERA (PSC, 2001) and do not take into account multipathway or multiconstituent exposures, impacts to ecological receptors, migration from soil to groundwater, or background concentrations of COPCs.
The HHERA PRALs were developed using the following target risk goals for individual COPCs:
Cancer Risk (CR) = 1E-06
Hazard Quotient (HQ) = 0.1
COPC – Constituent of Potential Concern
IPIMAL – Inhalation Pathway Interim Measure Action Level.
[1] Calculated using the Maximum GIVF for 1,1-DCE per IPIM Tech Memo 1.
[2] HEAST2 (Table 2), 1997.
[3] IRIS (1st Quarter), 2005.
[4] NCEA.
[5] NCEA value provided by Marcia Bailey.
[6] NTV - IPIMAL Surrogate Toxicity Value.
[7] Email from M.Bailey of USEPA 06/17/03.
[8] Email from M.Bailey of USEPA 09/18/02.
[9] No Value on IRIS 05, HEAST 97, or NCEA.

Table 2-3 – IDW Input Parameters

IDW Parameter	Parameters Used in Interpolation of CEFs	Description
Power	4	As the power increases, the grid node being interpolated is influenced more by points located closer than points located further away. The default value in many software applications (e.g., Surfer) is 2. For this analysis, a power of 4 was assumed which results in contours that are less smooth but are heavily influenced by points located closer to the grid node being interpolated. The power parameter must be greater than 0 and less than 20.
Smoothing	0	Smoothing was not incorporated into the contours. Normally, IDW behaves as an exact interpolator. When calculating a grid node, the weights assigned to the data points are fractions, and the sums of all the weights are equal to 1.0. When a particular observation is coincident with a grid node, the distance between that observation and the grid node is 0.0, and that observation is given a weight of 1.0, while all other observations are given weights of 0.0. Thus, the grid node is assigned the value of the coincident observation. The smoothing parameter buffers this behavior. If a non-zero smoothing parameter is used, no point is given an overwhelming weight (i.e., no point is given a weighting factor equal to 1.0).
Radius 1	250[a] feet	The radius of the search ellipse in the X direction (east-west: parallel to groundwater flow).
Radius 2	100[a] feet	The radius of the search ellipse in the Y direction (north-south: perpendicular to groundwater flow).
Search Sectors	4	The search ellipse was divided into 4 search sectors of equal size.
Anisotropy Angle	5^{o}	The anisotropy angle is the offset of the search ellipse in the X direction. An anisotropy angle of 5^{o} results in an orientation of the X coordinate of the search ellipse parallel to the groundwater flow located hydraulically down gradient of the Georgetown Facility.
Cell Spacing	2 feet	The cell spacing is the size of the node that will be assigned the interpolated value. Smaller cell spacing results in a smoother interpolation because more nodes are interpolated.

Table 2-4 – 5-Year Monitoring Plan for SSDS and SMDS Locations

Address	IPIM Mitigation System Type	IPIM Confirmation Sampling Schedule	Negative Pressure Field Extension Monitoring Schedule
710 S. Lucile IPIM LTM Group – Annual Groundwater, Ambient Air, and Indoor Air VOC Sampling. Biennial Negative Pressure Field Extension Monitoring			
710 S. Lucile (SDAJ)	SSD	2005, 2006, 2007, 2008, 2009	2005, 2007, 2009
747 S. Lucile IPIM LTM Group – Annual Groundwater, Ambient Air, and Indoor Air VOC Sampling. Biennial Negative Pressure Field Extension Monitoring			
747 S. Lucile (Western Trailer)	SSD	2005, 2006, 2007, 2008, 2009	2005, 2007, 2009
672/674 S. Lucile IPIM LTM Group – Annual Groundwater, Ambient Air, and Indoor Air VOC Sampling. Biennial Negative Pressure Field Extension Monitoring			
672/674 S. Lucile	SSD/SMD	2005 (initial CS), 2006, 2007, 2008, 2009	2005, 2007, 2009
5403 Maynard Ave. S. IPIM LTM Group – Biennial Negative Pressure Field Extension Monitoring			
5403 Maynard Ave. S.	SSD	--	2005, 2007, 2009
615 S. Brandon IPIM LTM Group – Groundwater, Ambient Air, and Crawl Space VOC Sampling in 2005 and 2009.			
615 S. Brandon	SMD	2005 (initial CS)	--
611/613 S. Brandon	SMD	2007	--
605 S. Brandon IPIM LTM Group – Groundwater, Ambient Air, and Crawl Space VOC Sampling in 2005 and 2009.			
605 S. Brandon	SSD/SMD	2005 (initial CS), 2009	2005
601 S. Brandon	SMD	--	--
402 S. Lucile IPIM LTM Group – Groundwater VOC Sampling in 2004.			
402 S. Lucile	SMD	2005 (initial CS)	--
412 S. Lucile IPIM LTM Group – Groundwater, Ambient Air, and Indoor Air VOC Sampling in 2005 and 2009. Biennial Negative Pressure Field Extension Monitoring			
412 S. Lucile	SSD	2009	2005, 2007, 2009
406 S. Lucile	SSD	--	2005, 2007, 2009
416 S. Lucile	SSD	--	2005, 2007, 2009
412 S. Orcas IPIM LTM Group – Biennial Negative Pressure Field Extension Monitoring			
412 S. Orcas	SSD	2005 (initial CS)	2005, 2007, 2009
404 S. Orcas	SSD	--	2005, 2007, 2009
406 S. Orcas	SSD	--	2005, 2007, 2009
218 S. Findlay IPIM LTM Group – Groundwater, Ambient Air, and Indoor Air VOC Sampling in 2011[a]. Biennial Negative Pressure Field Extension Monitoring			
218 S. Findlay	SSD	2011[a]	2005, 2007, 2009
215 S. Orcas IPIM LTM Group – Groundwater, Ambient Air, and Indoor Air VOC Sampling in 2009. Biennial Negative Pressure Field Extension Monitoring			
215 S. Orcas	SSD	2009	2005, 2007, 2009

Table 2-4 – 5-Year Monitoring Plan for SSDS and SMDS Locations

Address	IPIM Mitigation System Type	IPIM Confirmation Sampling Schedule	Negative Pressure Field Extension Monitoring Schedule
217 S. Orcas IPIM LTM Group – Groundwater, Ambient Air, and Indoor Air VOC Sampling in 2007. Biennial Negative Pressure Field Extension Monitoring			
217 S. Orcas	SSD/SMD	2007	2005, 2007, 2009
227 S. Orcas	SSD	--	2005, 2007, 2009
202 S Mead St. Group – Groundwater, Ambient Air, and Indoor Air VOC Sampling in 2013[a]. Biennial Negative Pressure Field Extension Monitoring			
202-228 Mead	SSD	2013[a]	2005, 2007, 2009
125 S. Findlay IPIM LTM Group – Biennial Groundwater VOC Sampling for At Least One Building in the Group.			
125 S. Findlay	SMD	2005 (initial CS)	--
125 S. Findlay	SMD	2007	--
121 S. Findlay	SMD	2009	--
122 S. Findlay	SMD	2011[a]	--
123 S. Findlay	SMD	2013[a]	--
5601 2nd Ave IPIM LTM Group – Biennial Groundwater, Ambient Air, and Crawl Space VOC Sampling for At Least One Building in the Group.			
5601 2nd Ave. S	SMD	2005 (initial CS)	--
5607 2nd Ave. S.	SMD	2007	--
5607 ½ 2nd Ave. S.	SMD	2009	--
5609 2nd Ave. S.	SMD	2011[a]	--
5601 2nd Ave. S	SMD	2013[a]	--
134 S. Mead IPIM LTM Group – Biennial Groundwater VOC Sampling for At Least One Building in the Group.			
134 S. Mead	SMD	2005 (initial CS)	--
128 S. Mead	SMD	2007	--
132 S. Mead	SMD	2009	--
134 S. Mead	SMD	2011[a]	--

Notes:
[a] These samples would only be collected if Ecology and PSC agree to continue with the IPIM LTM Plan after the 5-Year Review.
--Not applicable.
CS = Confirmation Sample.
IPIM = Inhalation Pathway Interim Measure.
LTM = Long Term Monitoring.
Negative Pressure Field Extension cannot be measured for Sub-Membrane Depressurization Systems.
SSD = Sub-Slab Depressurization System.
SMD = Sub-Membrane Depressurization System.
The VOC sampling schedule and Negative Pressure Extension Monitoring Schedule are tentative and may change depending on access to the buildings to sample. At least one building in each IPIM LTM Group will be sampled. In some cases the building scheduled for sampling may not be sampled if PSC cannot gain access. In these instances PSC will attempt to gain access to another building in the LTM Group and then collect the sample that is representative of buildings within the group.

Table 2-5a – Summary of Tier 1 CCEFs and NCCEFs for Residential Scenarios

Well ID	Bottom of Screen Interval (feet bgs)	Groundwater Sampling Time Period	Number of Quarters Samples Were Collected from this Well	Residential CCEFs				Residential NCCEFs			
				Minimum	Maximum	Mean	1Q06	Minimum	Maximum	Mean	1Q06
				CCEF	CCEF	CCEF	CCEF	NCCEF	NCCEF	NCCEF	NCCEF
112-S-1	15	2Q02 - 1Q06	16	3.30E+00	4.19E+01	1.32E+01	5.02E+00	2.18E-01	6.50E+00	3.10E+00	3.74E-01
113-S-1	15	2Q02 - 1Q06	14	1.40E+00	1.90E+01	8.29E+00	1.40E+00	1.34E-02	1.60E+01	6.81E+00	1.34E-02
CG-121-40	40	2Q02 - 1Q06	16	3.94E+00	1.20E+01	6.42E+00	3.94E+00	2.90E-03	7.08E-02	2.69E-02	4.74E-02
CG-122-WT	15	2Q02 - 1Q06	13	2.26E+00	9.81E+00	5.38E+00	2.26E+00	1.44E-02	1.72E-01	7.84E-02	1.72E-01
CG-124-WT	14.5	2Q02 - 1Q06	15	3.32E+01	1.20E+02	7.61E+01	3.32E+01	7.46E-02	3.50E+00	1.13E+00	7.46E-02
CG-126-WT	14.5	2Q02 - 1Q06	14	3.39E+01	7.70E+01	5.26E+01	3.84E+01	9.00E-02	3.25E-01	1.99E-01	1.15E-01
CG-127-WT	16	2Q02 - 1Q06	13	1.99E+01	5.00E+01	3.28E+01	1.99E+01	2.25E-02	1.70E-01	6.32E-02	2.85E-02
CG-128-WT	14.5	2Q02 - 1Q06	13	2.20E-01	4.20E+00	1.69E+00	1.00E+00	1.60E-03	1.13E-02	2.98E-03	5.77E-03
CG-129-WT	15	2Q02 - 1Q06	11	5.25E-02	2.60E-01	7.53E-02	--	2.13E-04	2.13E-04	1.94E-05	--
CG-130-WT	14	2Q02 - 1Q06	13	2.21E+00	5.98E+00	4.03E+00	3.00E+00	1.52E-02	6.50E-02	4.43E-02	5.10E-02
CG-131-WT	15	2Q02 - 1Q06	13	6.59E+01	1.70E+02	1.22E+02	6.59E+01	5.61E-01	2.00E+00	1.09E+00	5.61E-01
CG-134-WT	14.3	2Q02 - 1Q06	13	3.47E-02	8.94E-01	2.13E-01	2.44E-01	1.11E-03	2.10E-02	3.16E-03	7.20E-03
CG-135-40	40	2Q02 - 1Q06	9	3.90E+00	9.80E+00	6.41E+00	--	8.20E-03	3.13E-02	1.63E-02	--
CG-136-WT	14	2Q02 - 1Q06	13	4.06E+01	1.10E+02	7.86E+01	4.06E+01	6.50E-01	2.80E+00	1.54E+00	9.39E-01
CG-137-WT	14.5	2Q02 - 1Q06	13	5.59E+02	1.30E+03	8.41E+02	6.52E+02	6.01E-01	1.50E+00	9.47E-01	1.25E+00
CG-138-WT	14.5	2Q02 - 1Q06	13	4.84E-01	1.70E+00	7.88E-01	4.84E-01	3.72E-03	3.82E-03	5.80E-04	3.72E-03
CG-139-40	40	2Q02 - 1Q06	12	5.54E-01	3.94E+01	4.51E+00	--	0.00E+00	0.00E+00	0.00E+00	--
CG-140-WT	15	2Q02 - 1Q06	5	0.00E+00	0.00E+00	0.00E+00	--	0.00E+00	0.00E+00	0.00E+00	--

Table 2-5a – Summary of Tier 1 CCEFs and NCCEFs for Residential Scenarios

Well ID	Bottom of Screen Interval (feet bgs)	Groundwater Sampling Time Period	Number of Quarters Samples Were Collected from this Well	Residential CCEFs				Residential NCCEFs			
				Minimum	Maximum	Mean	1Q06	Minimum	Maximum	Mean	1Q06
				CCEF	CCEF	CCEF	CCEF	NCCEF	NCCEF	NCCEF	NCCEF
CG-141-WT	14.5	2Q02 - 1Q06	11	7.30E-02	3.13E+00	5.38E-01	--	4.74E-03	1.20E-02	1.52E-03	--
CG-142-WT	15	2Q02 - 1Q06	11	3.57E-02	6.70E-02	9.34E-03	--	0.00E+00	0.00E+00	0.00E+00	--
CG-143-WT	14.5	2Q02 - 1Q06	11	6.00E-02	2.77E-01	1.17E-01	--	0.00E+00	0.00E+00	0.00E+00	--
CG-144-35	35	2Q02 - 1Q06	11	4.43E-01	5.60E+00	1.54E+00	--	3.30E-03	3.30E-03	3.00E-04	--
CG-145-35	35	2Q02 - 1Q06	11	2.41E-02	1.89E-01	9.58E-02	--	1.40E-03	6.53E-03	1.66E-03	--
CG-151-25	25	2Q02 - 1Q06	3	4.77E+01	1.11E+02	7.50E+01	--	1.99E-02	1.53E-01	5.75E-02	--

-- = Well was not sampled during this quarter.

1Q06 = 1st Quarter 2006.

bgs = Feet below ground surface.

CCEF - Cancer Cumulative Exceedance Factor.

NCCEF - Noncancer Cumulative Exceedance Factor.

The CCEFs and NCCEFs presented in this table are based on groundwater IPIMALs developed through the GIVF method presented in IPIM Tech Memo 1 (PSC, 2002).

The IPIMALs were calculated using the following target risk goals for individual COPCs: cancer risk (CR) = 1E-06; Hazard Quotient (HQ) = 0.1

Table 2-5b – Summary of Tier 2 CCEFs and NCCEFs for Commercial Scenarios

Well ID	Bottom of Screen Interval (feet bgs)	Groundwater Sampling Time Period	Number of Quarters Samples Were Collected from this Well	Commercial NCCEFs				Commercial CCEFs			
				Minimum	Maximum	Mean	1Q06	Minimum	Maximum	Mean	1Q06
				CCEF	CCEF	CCEF	CCEF	NCCEF	NCCEF	NCCEF	NCCEF
112-S-1	15	2Q02 - 1Q06	16	1.27E+00	1.55E+01	5.06E+00	2.15E+00	5.12E-02	1.50E+00	7.16E-01	8.78E-02
113-S-1	15	2Q02 - 1Q06	14	5.86E-01	6.40E+00	3.00E+00	5.86E-01	3.15E-03	3.70E+00	1.57E+00	3.15E-03
CG-121-40	40	2Q02 - 1Q06	16	1.37E+00	4.20E+00	2.23E+00	1.37E+00	6.80E-04	1.66E-02	6.31E-03	1.11E-02
CG-122-WT	15	2Q02 - 1Q06	13	8.35E-01	3.45E+00	1.90E+00	8.35E-01	3.37E-03	4.05E-02	1.83E-02	4.05E-02
CG-124-WT	14.5	2Q02 - 1Q06	15	1.44E+01	4.61E+01	3.10E+01	1.44E+01	1.75E-02	8.20E-01	2.66E-01	1.75E-02
CG-126-WT	14.5	2Q02 - 1Q06	14	1.49E+01	3.10E+01	2.19E+01	1.70E+01	2.11E-02	7.64E-02	4.68E-02	2.71E-02
CG-127-WT	16	2Q02 - 1Q06	13	8.81E+00	2.00E+01	1.36E+01	8.81E+00	5.28E-03	4.10E-02	1.50E-02	6.69E-03
CG-128-WT	14.5	2Q02 - 1Q06	13	7.10E-02	1.70E+00	6.90E-01	4.21E-01	3.90E-04	2.66E-03	7.01E-04	1.35E-03
CG-129-WT	15	2Q02 - 1Q06	11	2.33E-02	1.00E-01	3.08E-02	--	5.00E-05	5.00E-05	4.54E-06	--
CG-130-WT	14	2Q02 - 1Q06	13	9.74E-01	2.54E+00	1.65E+00	1.29E+00	3.57E-03	1.53E-02	1.04E-02	1.20E-02
CG-131-WT	15	2Q02 - 1Q06	13	2.92E+01	6.75E+01	5.03E+01	2.92E+01	1.32E-01	4.60E-01	2.53E-01	1.32E-01
CG-134-WT	14.3	2Q02 - 1Q06	13	1.21E-02	3.22E-01	8.15E-02	9.04E-02	2.60E-04	5.00E-03	7.44E-04	1.69E-03
CG-135-40	40	2Q02 - 1Q06	9	1.36E+00	3.40E+00	2.23E+00	--	1.90E-03	7.50E-03	3.85E-03	--
CG-136-WT	14	2Q02 - 1Q06	13	1.80E+01	4.50E+01	3.28E+01	1.80E+01	1.50E-01	6.59E-01	3.63E-01	2.21E-01
CG-137-WT	14.5	2Q02 - 1Q06	13	2.48E+02	5.20E+02	3.50E+02	2.89E+02	1.41E-01	3.60E-01	2.24E-01	2.94E-01
CG-138-WT	14.5	2Q02 - 1Q06	13	1.92E-01	7.11E-01	3.25E-01	1.92E-01	8.73E-04	8.98E-04	1.36E-04	8.73E-04

Table 2-5b – Summary of Tier 2 CCEFs and NCCEFs for Commercial Scenarios

Well ID	Bottom of Screen Interval (feet bgs)	Groundwater Sampling Time Period	Number of Quarters Samples Were Collected from this Well	Commercial NCCEFs				Commercial CCEFs			
				Minimum	Maximum	Mean	1Q06	Minimum	Maximum	Mean	1Q06
				CCEF	CCEF	CCEF	CCEF	NCCEF	NCCEF	NCCEF	NCCEF
CG-139-40	40	2Q02 - 1Q06	12	1.93E-01	1.36E+01	1.56E+00	--	0.00E+00	0.00E+00	0.00E+00	--
CG-140-WT	15	2Q02 - 1Q06	5	0.00E+00	0.00E+00	0.00E+00	--	0.00E+00	0.00E+00	0.00E+00	--
CG-141-WT	14.5	2Q02 - 1Q06	11	2.92E-02	1.18E+00	2.03E-01	--	1.11E-03	2.90E-03	3.65E-04	--
CG-142-WT	15	2Q02 - 1Q06	11	1.24E-02	2.40E-02	3.31E-03	--	0.00E+00	0.00E+00	0.00E+00	--
CG-143-WT	14.5	2Q02 - 1Q06	11	2.67E-02	1.21E-01	4.75E-02	--	0.00E+00	0.00E+00	0.00E+00	--
CG-144-35	35	2Q02 - 1Q06	11	1.54E-01	2.00E+00	5.37E-01	--	7.75E-04	7.75E-04	7.05E-05	--
CG-145-35	35	2Q02 - 1Q06	11	8.35E-03	6.55E-02	3.37E-02	--	3.20E-04	1.53E-03	3.89E-04	--
CG-151-25	25	2Q02 - 1Q06	3	1.65E+01	3.86E+01	2.61E+01	--	4.66E-03	3.59E-02	1.35E-02	--

-- = Well was not sampled during this quarter.

1Q06 = 1st Quarter 2006.

bgs = Feet below ground surface.

CCEF - Cancer Cumulative Exceedance Factor.

NCCEF - Noncancer Cumulative Exceedance Factor.

The CCEFs and NCCEFs presented in this table are based on groundwater IPIMALs developed through the GIVF method presented in IPIM Tech Memo 1 (PSC, 2002).

The IPIMALs were calculated using the following target risk goals for individual COPCs: cancer risk (CR) = 1E-06; Hazard Quotient (HQ) = 0.1

Table 2-6 – Summary of Buildings Evaluated in Tier 3 and Tier 4 of the IPIM Decision Tree

Location	*Building Type*	*Location Proceeded to Tier 4?*	*Comments*
Tier 3 Locations			
111 S Mead St - 316 S Fidalgo S (111 S Mead St, 316 S Fidalgo St, & 5801 2nd Ave S)	Commercial	To Be Determined By Ecology	Tier 3 sampling pending. Non-PSC facility with release to groundwater. 3rd party responsible for future IPIM investigation/mitigation.
203 S Orcas St	Commercial	No	Tier 3 sampling completed (groundwater only) and results were below Ecology's risk benchmarks. This location returned to Tier 2.
211 S Orcas St	Residential	No	Tier 3 sampling completed (groundwater only) and results were below Ecology's risk benchmarks. This location returned to Tier 1.
214 S Findlay St	Residential	No	Tier 3 sampling completed (groundwater only) and results were below Ecology's risk benchmarks. This location returned to Tier 1.
215 S Findlay St (215 - 227 S Findlay St)	Commercial	To Be Determined By Ecology	PSC conducted initial Tier 3 sampling and indoor air concentrations exceeded IPIMALs. Location is impacted by a non-PSC facility with release to groundwater. 3rd party responsible for future IPIM investigation/mitigation.
220 S Findlay St	Commercial	To Be Determined By Ecology	Tier 3 sampling pending. 3rd party is responsible for IPIM investigation/mitigation.
222 S Orcas St	Commercial	No	Tier 3 sampling completed (groundwater only) and results were below Ecology's risk benchmarks. This location returned to Tier 2.
226 S Orcas St	Commercial	No	Tier 3 sampling completed (groundwater only) and results were below Ecology's risk benchmarks. This location returned to Tier 2.
301 S Findlay St (301 - 313 S Findlay St)	Commercial	To Be Determined By Ecology	Tier 3 sampling pending. 3rd party is responsible for IPIM investigation/mitigation.
308 S Orcas St	Commercial	No	Tier 3 sampling completed and results were below Ecology's risk benchmarks. This location returned to Tier 2.
312 S Findlay St (5516 3rd Ave S)	Commercial	To Be Determined By Ecology	Tier 3 sampling pending. Non-PSC facility with release to groundwater. 3rd party responsible for future IPIM investigation/mitigation.
318 S Findlay St	Commercial	To Be Determined By Ecology	Tier 3 sampling pending. Non-PSC facility with release to groundwater. 3rd party responsible for future IPIM investigation/mitigation.
500 S Findlay St (500 - 520 S. Findlay St & 5601 -	Commercial	No	No Tier 3 sampling at this location. Building has a 1st floor parking garage. This

Table 2-6 – Summary of Buildings Evaluated in Tier 3 and Tier 4 of the IPIM Decision Tree

Location	*Building Type*	*Location Proceeded to Tier 4?*	*Comments*
Tier 3 Locations			
5621 6th Ave S)			location returned to Tier 2.
500 S Lucile St (502 - 580 S Lucile St)	Commercial	No	Tier 3 sampling completed and results were below Ecology's risk benchmarks. This location returned to Tier 2.
507 S Brandon St	Residential	No	Tier 3 sampling completed (GIVF location) and results were below Ecology's risk benchmarks. This location returned to Tier 1.
508 S Mead St (5701 6th Ave S)	Commercial	Location was Resampled	This location was resampled in April 2006 and a Tier 3 report for Ecology is pending.
519 S Brandon St (519 - 521 S. Brandon St.)	Commercial	No	Tier 3 sampling completed and results were below Ecology's risk benchmarks. This location returned to Tier 2.
527 S Lucile St (5501 - 5519 6th Ave S)	Commercial	No	Tier 3 sampling completed and results were below Ecology's risk benchmarks. This location returned to Tier 2.
5327 Denver Ave S	Residential	No	Tier 3 sampling completed (GIVF location) and results were below Ecology's risk benchmarks. This location returned to Tier 1.
5412 6th Ave S	Commercial	No	Tier 3 sampling completed and results were below Ecology's risk benchmarks. This location returned to Tier 2.
5413 Maynard Ave S	Commercial	No	Tier 3 sampling completed and results were below Ecology's risk benchmarks. This location returned to Tier 2.
5506 6th Ave S	Commercial	No	Tier 3 sampling completed and results were below Ecology's risk benchmarks. This location returned to Tier 2.
5600 6th Ave S (5600 - 5620 6th Ave S)	Commercial	No	Tier 3 sampling completed and results were below Ecology's risk benchmarks. This location returned to Tier 2.
5602 2nd Ave S	Residential	No	Tier 3 sampling completed and results were below Ecology's risk benchmarks. This location returned to Tier 1.
5606 2nd Ave S	Residential	No	Tier 3 sampling completed and results were below Ecology's risk benchmarks. This location returned to Tier 1.
5610 2nd Ave S	Residential	No	Tier 3 sampling completed (groundwater only) and results were below Ecology's risk benchmarks. This location returned to Tier 1.
5610 4th Ave S	Commercial	No	Tier 3 sampling completed and results were below Ecology's risk benchmarks.

Table 2-6 – Summary of Buildings Evaluated in Tier 3 and Tier 4 of the IPIM Decision Tree

Location	*Building Type*	*Location Proceeded to Tier 4?*	*Comments*
Tier 3 Locations			
			This location returned to Tier 2.
5700 3rd Ave S (5700 3rd Ave S & 309 S Orcas St)	Commercial	To Be Determined By Ecology	PSC conducted initial Tier 3 sampling and indoor air concentrations exceeded IPIMALs. Non-PSC facility with release to groundwater. 3rd party responsible for future IPIM investigation/mitigation.
5706 2nd Ave S (5706 2nd Ave S & 200 S Mead St)	Commercial	No	Tier 3 sampling completed and results were below Ecology's risk benchmarks. This location returned to Tier 2.
5900 1st Ave S	Commercial	To Be Determined By Ecology	PSC conducted initial Tier 3 sampling and indoor air concentrations exceeded IPIMALs. Location is impacted by a non-PSC facility with release to groundwater. 3rd party responsible for future IPIM investigation/mitigation.
612 S Orcas St (620 S Orcas St)	Commercial	No	Tier 3 sampling completed and results were below Ecology's risk benchmarks. This location returned to Tier 2.
624 S Findlay St	Commercial	To Be Determined By Ecology	Owner denied PSC access to collect Tier 3 samples.
650 S Lucile St (650 - 670 S Lucile St)	Commercial	No	Tier 3 sampling completed and results were below Ecology's risk benchmarks. This location returned to Tier 2.
665 S Lucile St (637, 665, & 667 S Lucile St)	Commercial	No	Tier 3 sampling completed and results were below Ecology's risk benchmarks. This location returned to Tier 2.

Table 2-6 – Summary of Buildings Evaluated in Tier 3 and Tier 4 of the IPIM Decision Tree (continued)

Location	*Building Type*	*IPIM System Installed?*	*Comments*
Tier 4 Locations			
118 S Findlay St		No	This location has been removed from the Tier 4 list with approval of Ecology (building has been demolished).
121 S Findlay St	Residential	Yes	IPIM installation complete & approved by Ecology.
122 S Findlay St	Residential	Yes	IPIM installation complete & approved by Ecology.
123 S Findlay St	Residential	Yes	IPIM installation complete & approved by Ecology.
125 S Findlay St	Residential	Yes	IPIM installation complete & approved by Ecology.
128 S Mead St	Residential	Yes	IPIM installation complete & approved by Ecology.
132 S Mead St	Residential	Yes	IPIM installation complete & approved by Ecology.
134 S Mead St	Residential	Yes	IPIM installation complete & approved by Ecology.
202 S Mead St (202 - 228 S Mead St)	Commercial	No	Tier 3 sampling completed. Location is impacted by a non-PSC facility with release to groundwater. 3rd party responsible for IPIM investigation/mitigation.
215 S Orcas St	Residential	Yes	IPIM installation complete & approved by Ecology.
217 S Orcas St	Residential	Yes	IPIM installation complete & approved by Ecology.
218 S Findlay St	Residential	Yes	IPIM installation complete & approved by Ecology.
227 S Orcas St	Residential	Yes	IPIM installation complete & approved by Ecology.
317 S Lucile St	Residential	No	Owner does not want IPIM installed.
402 S Lucile St	Commercial	Yes	IPIM installation complete & approved by Ecology.
404 S Orcas St	Residential	Yes	IPIM installation complete & approved by Ecology.
406 S Lucile St	Residential	Yes	IPIM installation complete & approved by Ecology.
406 S Orcas St (406 & 408 S Orcas St)	Residential	Yes	IPIM installation complete & approved by Ecology.
412 S Lucile St	Residential	Yes	IPIM installation complete & approved by Ecology.
412 S Orcas St	Residential	Yes	IPIM installation complete & approved by Ecology.

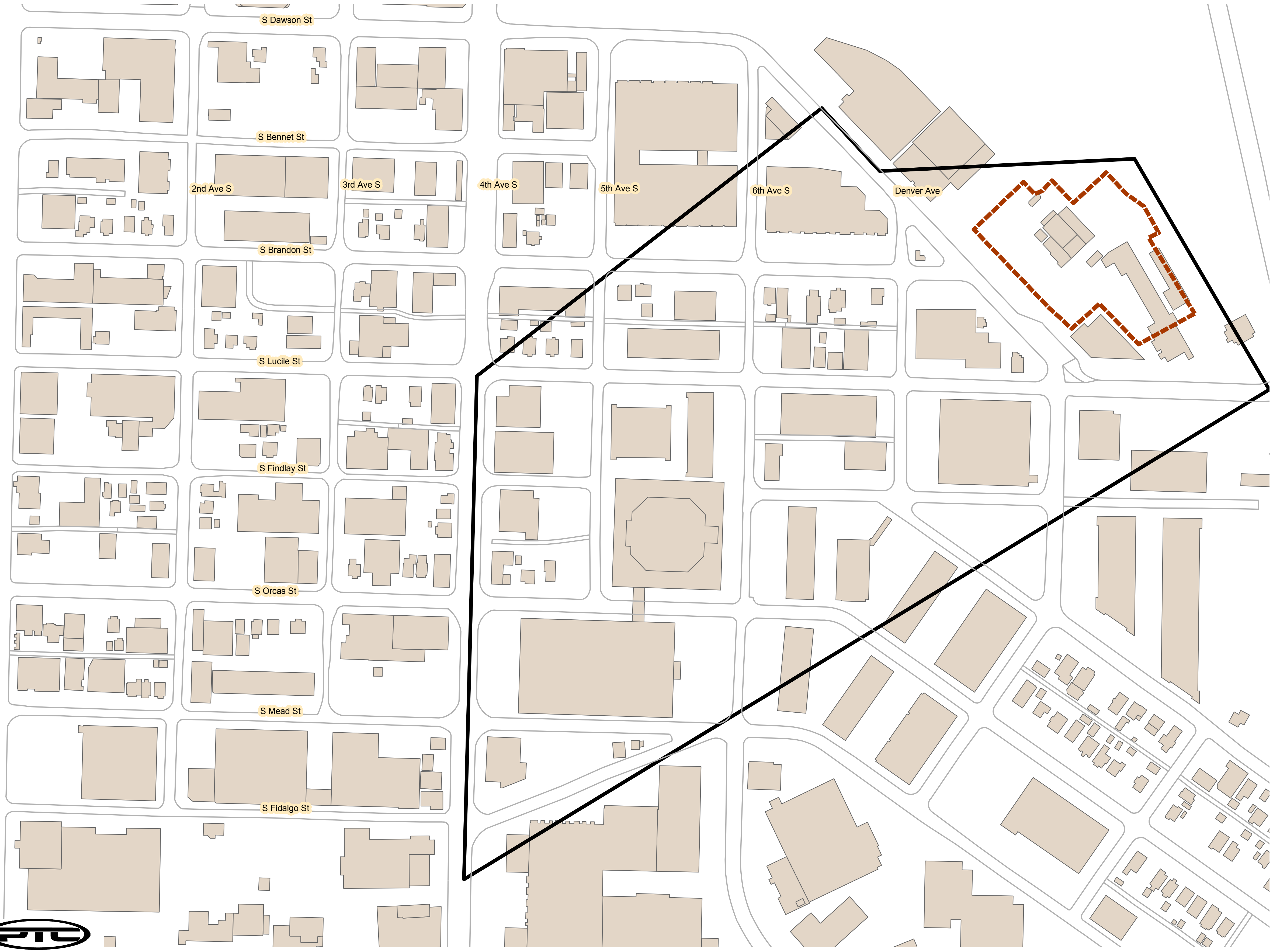
Table 2-6 – Summary of Buildings Evaluated in Tier 3 and Tier 4 of the IPIM Decision Tree (continued)

Location	***Building Type***	***IPIM System Installed?***	***Comments***
Tier 4 Locations			
416 S Lucile St	Residential	Yes	IPIM installation complete & approved by Ecology.
5403 Maynard Ave S	Residential	Yes	IPIM installation complete & approved by Ecology.
5409 Denver Ave S	Residential	No	Owner does not want IPIM installed.
5601 2nd Avee S	Residential	Yes	IPIM installation complete & approved by Ecology.
5607 1/2 2nd Ave S	Residential	Yes	IPIM installation complete & approved by Ecology.
5607 2nd Ave S	Residential	Yes	IPIM installation complete & approved by Ecology.
5607 4th Ave S	Residential	No	This location has been removed from the Tier 4 list with approval of Ecology. Owner has not responded to letters/phone calls requesting access to install IPIM.
5609 2nd Ave S	Commercial	Yes	IPIM installation complete & approved by Ecology.
601 S Brandon St	Residential	Yes	IPIM installation complete & approved by Ecology.
605 S Brandon St	Residential	Yes	IPIM installation complete & approved by Ecology.
611 S Brandon St (611 & 613 S Brandon St)	Residential	Yes	IPIM installation complete & approved by Ecology.
612 S Lucile St	Residential	No	This location has been removed from the Tier 4 list with approval of Ecology. No one lives in this building and the building is not connected to any utilties).
615 S Brandon St	Residential	Yes	IPIM installation complete & approved by Ecology.
616 S Lucile St	Residential	No	PSC is waiting for access from owner to install IPIM.
674 S Lucile St (672 & 674 S Lucile St)	Residential	Yes	IPIM installation complete & approved by Ecology.
701 S Lucile St (701 & 707 S Lucile St)	Commercial	Yes	IPIM installation complete & approved by Ecology.
710 S Lucile St	Commercial	Yes	IPIM installation complete & approved by Ecology.

Table 4-1 – Comparison of Literature Values Representing Background Indoor Air to Risk-based Limits for TCE and Tetrachloroethylene (PCE) (ug/m^3)

COPC	Range of Median Values in Indoor Air NJDEP VI Guidance[1]	Median Value in Indoor Air NYSDOH Indoor Air Survey[2]	Median Value in Indoor Air NHEXAS Study[3]	Range of Values in Indoor Air BASE Study[4]	USEPA Region III Risk-Based Limit[5]	USEPA Region IX Risk-Based Limit[6]	Draft USEPA Target Indoor Air Concentration Table 2c[7]
TCE	0.25 – 2.7	< 0.25	0.56	0.2 – 18	0.016	0.017	0.022
PCE	0.8 – 8.3	0.34	1.89	0.3 – 50	0.31	0.32	0.81

[1] Median concentrations in background indoor air samples summarized for ten studies in Table F-1, NJDEP VI Guidance Document (2005a).
[2] Median concentration measured from study of VOCs in indoor air of fuel oil heated homes, conducted in New York between 1997 and 2003 by New York State Department of Health (NYSDOH, revised November 14, 2005).
[3] Presented in Appendix 1 of Minnesota Department of Health (MDH) Indoor Air Sampling Guidance (updated 1/8/2004) from National Human Exposure Assessment Survey (NHEXAS): Distributions and Associations of Lead, Arsenic, and Volatile Organic Constituents in USEPA Region 5. (Clayton et. al.,1999).
[4] Range of quantifiable concentrations in indoor air measured from 56 U.S. buildings from Building Assessment Survey and Evaluation study (BASE), initiated in 1994 (Girman et. al., 1999).
[5] USEPA Region III Risk-based Concentration Table, updated October 26, 2005.
[6] USEPA Region IX Preliminary Remediation Goals (PRG) Table, updated December 28, 2004.
[7] USEPA Draft Subsurface Vapor Intrusion Guidance (USEPA, 2002). Table 2c: Generic Screening Levels- target indoor air concentration to satisfy target risk level of 1E-06 and hazard index (HI) of 1.0.



Legend

- Roads
- HCIM Area
- Site Wide Feasibilty Study Area
- Buildings

0 75 150 300 450 600 Feet

Notes

HCIM - Hydraulic Control Interim Measure

PSC Site Wide Feasibility Study Area

PSC Georgetown
May 2006

Figure 1-1

PIONEER TECHNOLOGIES CORPORATION

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Figure 2-1 – IPIM Decision Tree

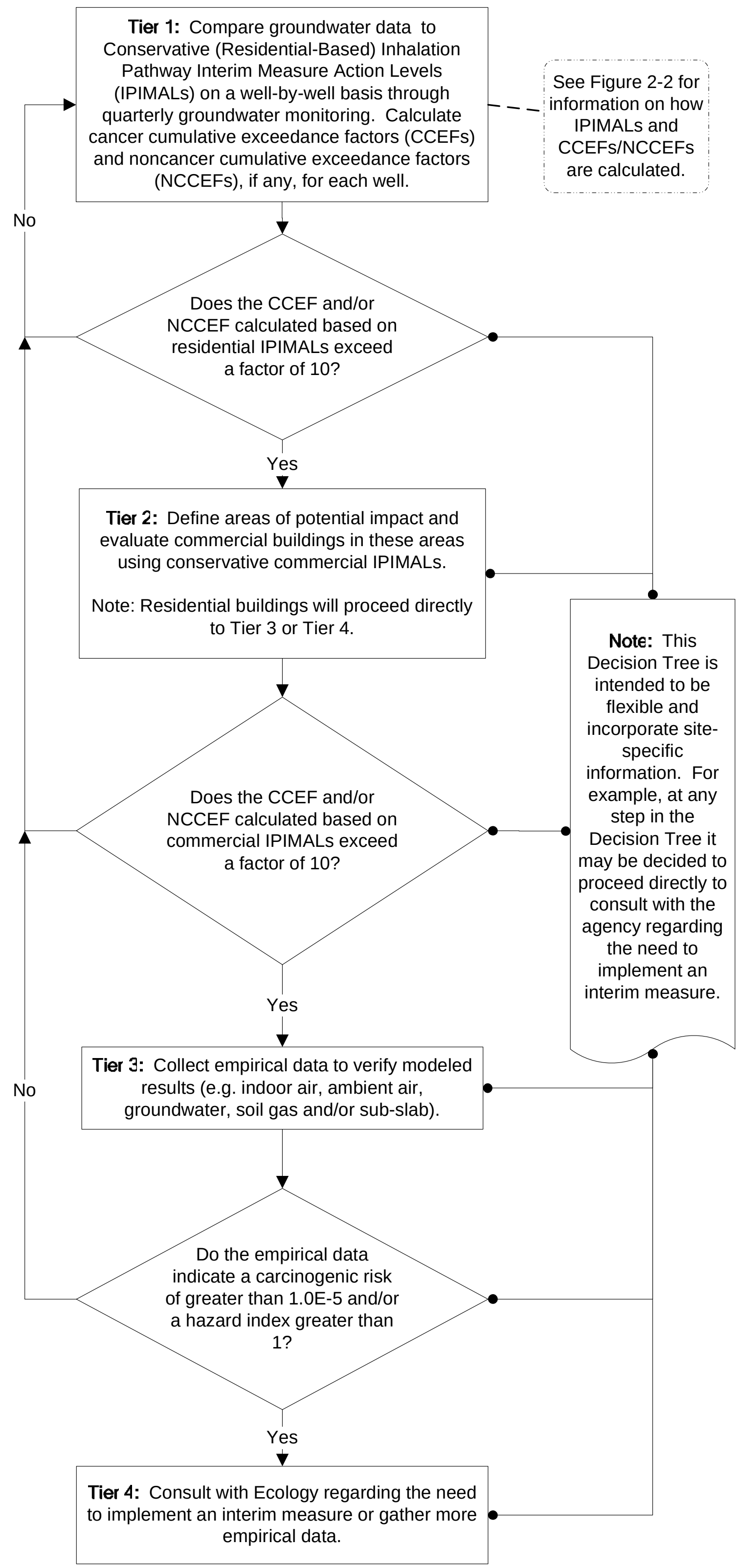
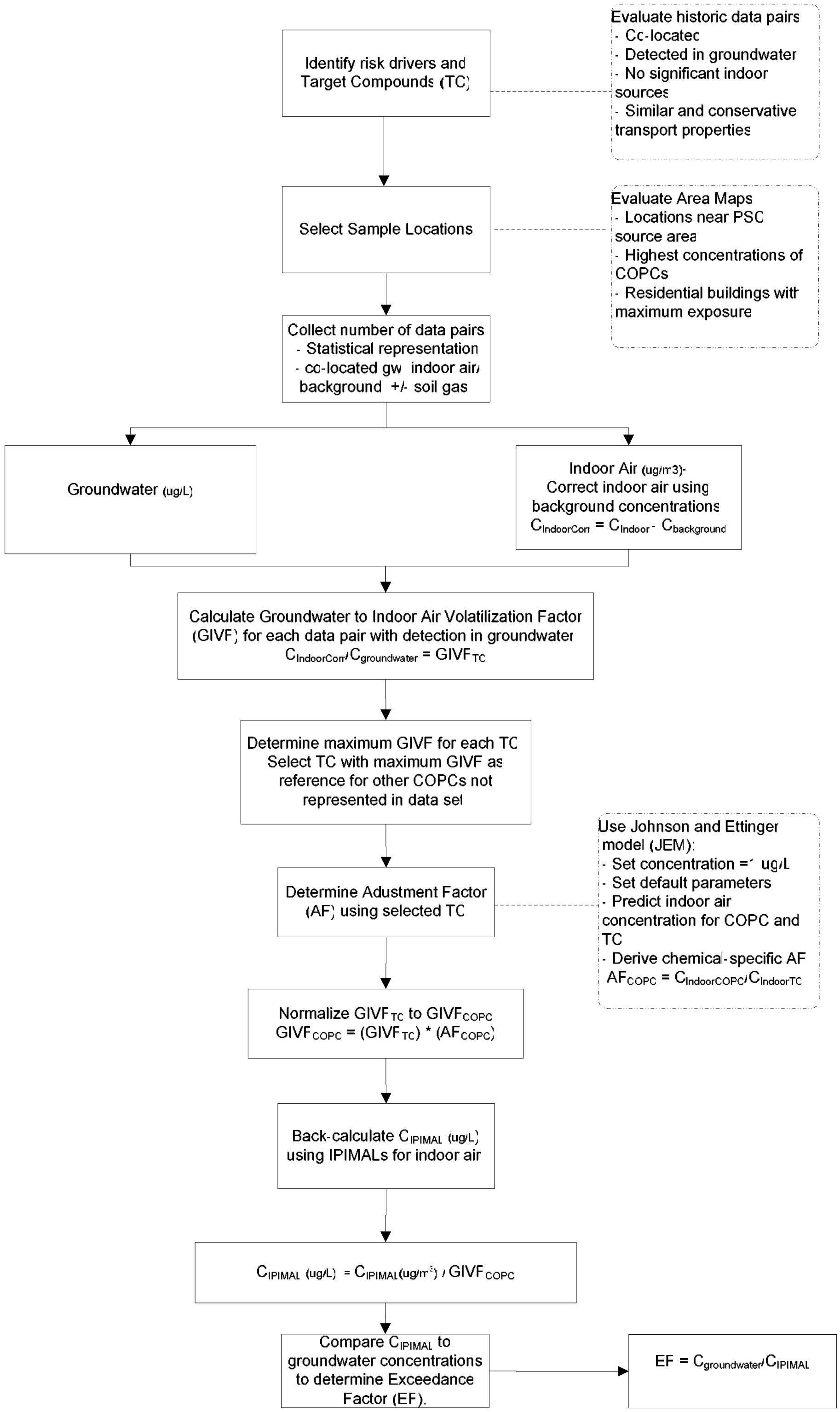


Figure 2-2 – Approach for Developing Groundwater IPIMALs



Legend

Wells

- Direct Push Well
- Groundwater Monitoring Well
- Roads
- HCIM Area
- Site Wide Feasibilty Study Area
- Area 3
- Co-Mingled Plume Area
- Areas 1 and 2
- Buildings

0 75 150 300 450 600 Feet

Notes

-HCIM - Hydraulic Control Interim Measure

- Areas 1, 2, and 3 were designated in the Draft Risk Assessment PSC 2001.

Groundwater Monitoring Well and Direct Push Locations Evaluated in Tier 1 and Tier 2

PSC Georgetown
May 2006

Figure 2-3

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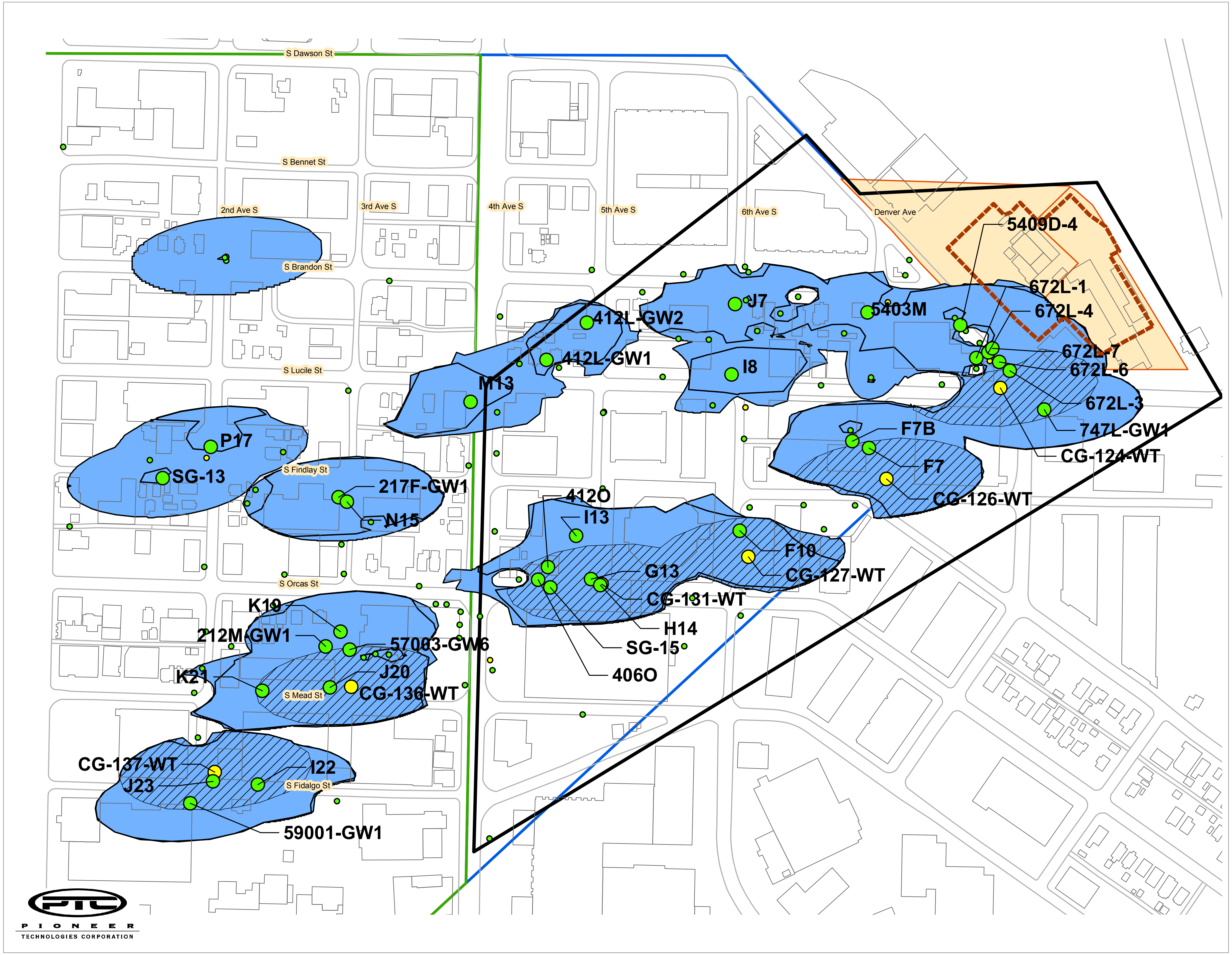


Legend

- 1Q06 Well Results with CCEF >=10
- Historical Well Results with CCEF >=10
- 1Q06 Well Results with CCEF <10
- Historical Well Results with CCEF <10
- Roads
- Buildings
- HCIM Area
- Site Wide Feasibilty Study Area
- Areas 1 and 2
- Area 3
- Co-Mingled Plume Area
- 1Q06 IPIM Residential CCEFs > 10*
- Previous Monitoring Results > 10 CCEF**

0 75 150 300 450 600 Feet

Notes

- Noncancer Exceedances are Co-Located with the Cancer Exceedances.

- IPIMALs for Groundwater are based on a carcinogenic risk of 1E-6 and Hazard Quotient of 0.1.

- Areas 1, 2, and 3 were designated in the Draft Risk Assessment PSC 2001.

- HCIM = Hydraulic Control Interim Measure

- IDW = Inverse Distance Weighting Interpolation

- Shallow Monitoring Wells Sampled in Area 3 and the Co-Mingled Plume area during 4th Quarter 2005 included: CG-121-40, CG-139-40, CG-144-35, CG-145-35 and CG-151-25.

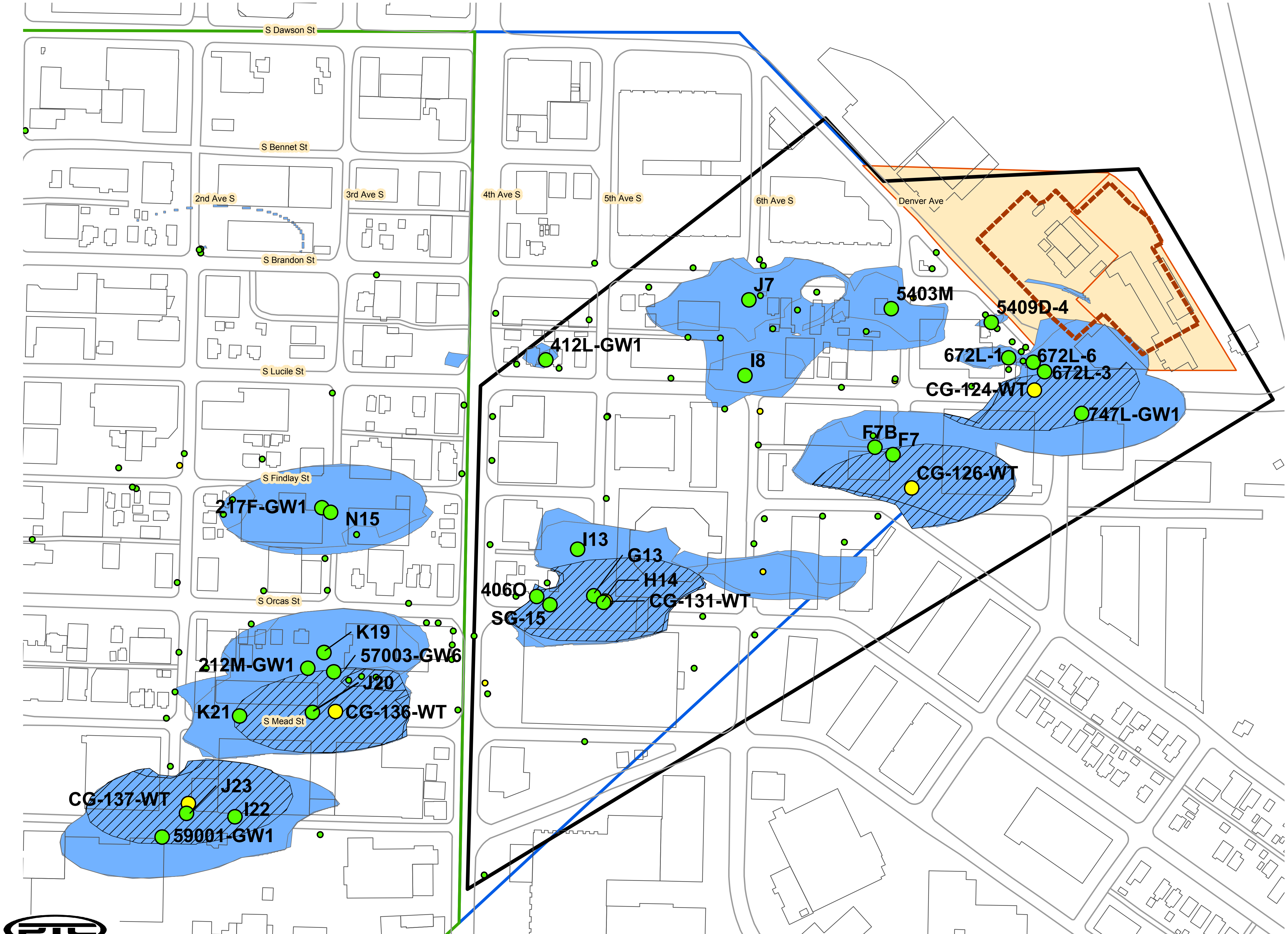
* Based on 1Q06 monitoring well data only (if the well was sampled). Otherwise, based on the most recent results for the monitoring well.

** Based on 2Q02, 3Q02, 4Q02, All Quarters 2003, 2004 and 2005 Monitoring Well and Direct Push Results.

Comparison of Residential CCEFs > 10 for 1Q06 Groundwater Monitoring Well Results <u>Only</u> with Previous Monitoring Results for Both Monitoring Wells and Direct Push Wells

PSC Georgetown
May 2006

Figure 2-4



Legend

- 1Q06 Well Results with CCEF >=10
- Historical Well Results with CCEF >=10
- 1Q06 Well Results with CCEF <10
- Historical Well Results with CCEF <10
- Roads
- Buildings
- HCIM Area
- Site Wide Feasibilty Study Area
- Areas 1 and 2
- Area 3
- Co-Mingled Plume Area
- 1Q06 IPIM Commercial CCEFs > 10*
- Previous Monitoring Results > 10 CCEF**

0 60 120 240 360 480 Feet

Notes

- Noncancer Exceedances are Co-Located with the Cancer Exceedances.

- IPIMALs for Groundwater are based on a carcinogenic risk of 1E-6 and Hazard Quotient of 0.1.

- Areas 1, 2, and 3 were designated in the Draft Risk Assessment PSC 2001.

- HCIM = Hydraulic Control Interim Measure

- IDW = Inverse Distance Weighting Interpolation

- Shallow Monitoring Wells Sampled in Area 3 and the Co-Mingled Plume area during 4th Quarter 2005 included: CG-121-40, CG-139-40, CG-144-35, CG-145-35 and CG-151-25.

* Based on 1Q06 monitoring well data (if the well was sampled). Otherwise, based on the most recent results for the monitoring well.

** Based on 2Q02, 3Q02, 4Q02, All Quarters 2003, 2004 and 2005 Monitoring Well and Direct Push Results.

Comparison of Commercial CCEFs > 10 for 1Q06 Groundwater Monitoring Well Results Only with Previous Monitoring Results for Both Monitoring Wells and Direct Push Wells

PSC Georgetown
April 2006

Figure 2-5

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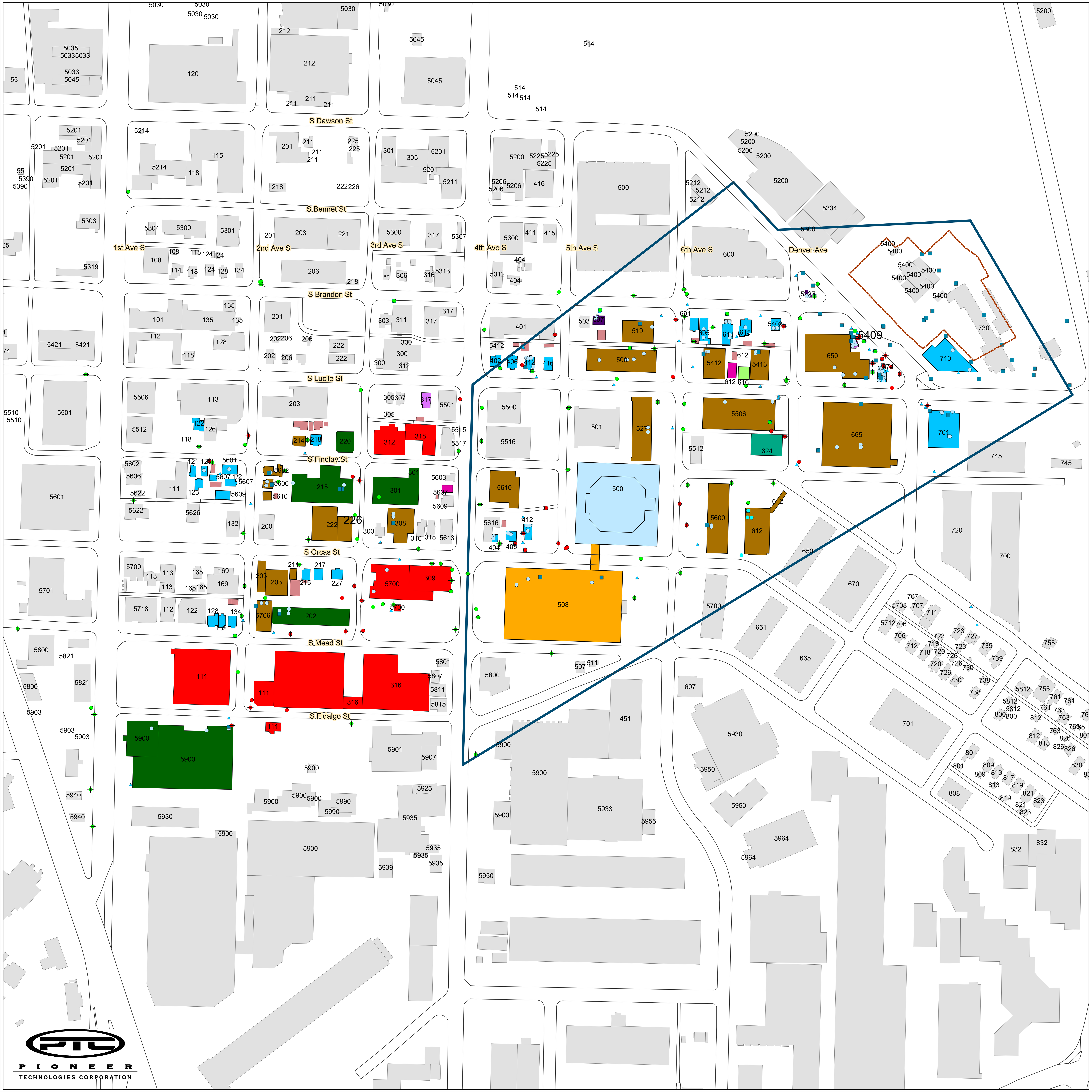


Legend

Residential Groundwater Cancer Cumulative Exceedance Factors

- < 10
- >= 10 to 50
- > 50

Tier 3/GIVF Media

- IndoorAir
- AmbientAir
- SoilGas
- Roads
- HCIM Area
- Site Wide Feasibility Study Area

VI Investigation Buildings

- Non-PSC Facility with Release to Groundwater
- 3rd Party Responsible for IPIM Investigation/Mitigation
- Continue Tier 1 and 2 Groundwater Monitoring
- Tier 3: Sampling Pending
- Tier 3: Waiting for Access from Owner to Sample
- Tier 3: Sampling Completed - Location to be Resampled
- Tier 3: Owner Declined Sampling
- Tier 3: No Sampling - Bldg Has 1st Floor Parking Garage - NFA
- Tier 3: Sampling Completed - Monitor GW
- GIVF Sampling Location: Monitor GW
- Tier 4: Waiting for Access from Owner to Install IPIM
- Tier 4: IPIM Installation Complete & Approved by Ecology
- Tier 4: Owner Does Not Want IPIM Installed
- Tier 4: This Location Has Been Removed From the Tier 4 List
- Garage/Shed - IPIM Not Required At This Structure

0 75 150 300 450 600 Feet

Notes

- Field reconnaissance performed by Tasya Gray from PSC and Jenifer Hill from PTC to validate buildings and addresses on January 27th and February 7th 2003.
- HCIM - Hydraulic Control Interim Measure
- NFA - No Further Action
- PSC - Philip Services Corporation
- PTC - PIONEER Technologies Corporation
- Based on IPIM Tech Memos 1, 2, 3 and 4 (PSC, 2003).

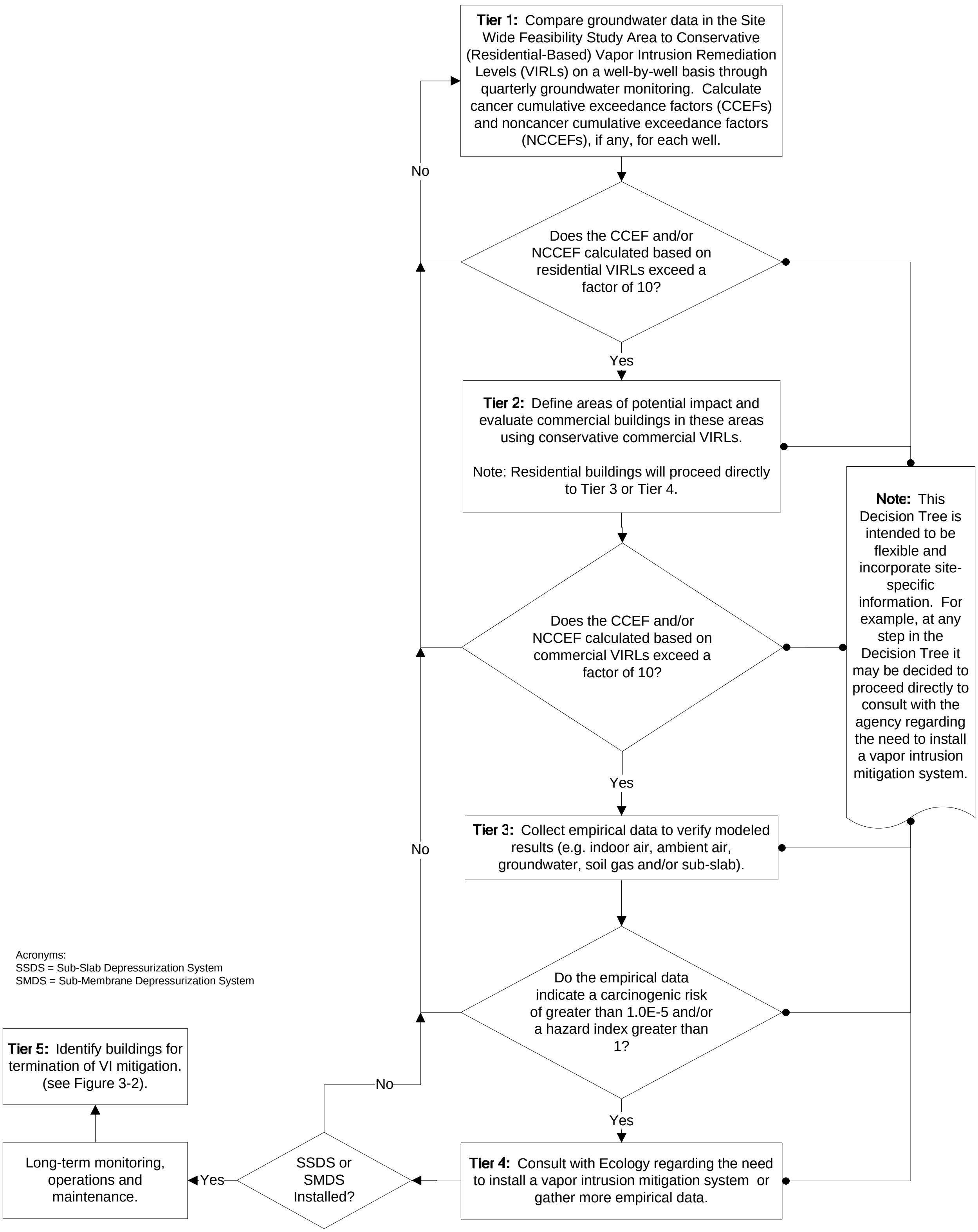
* Buildings noted as "Addresses Not Field Verified" have addresses associated with them from the City of Seattle, but have not been field checked by PSC and PTC.

Status of Locations Evaluated Under the IPIM Decision Tree

PSC - Georgetown
May 2006

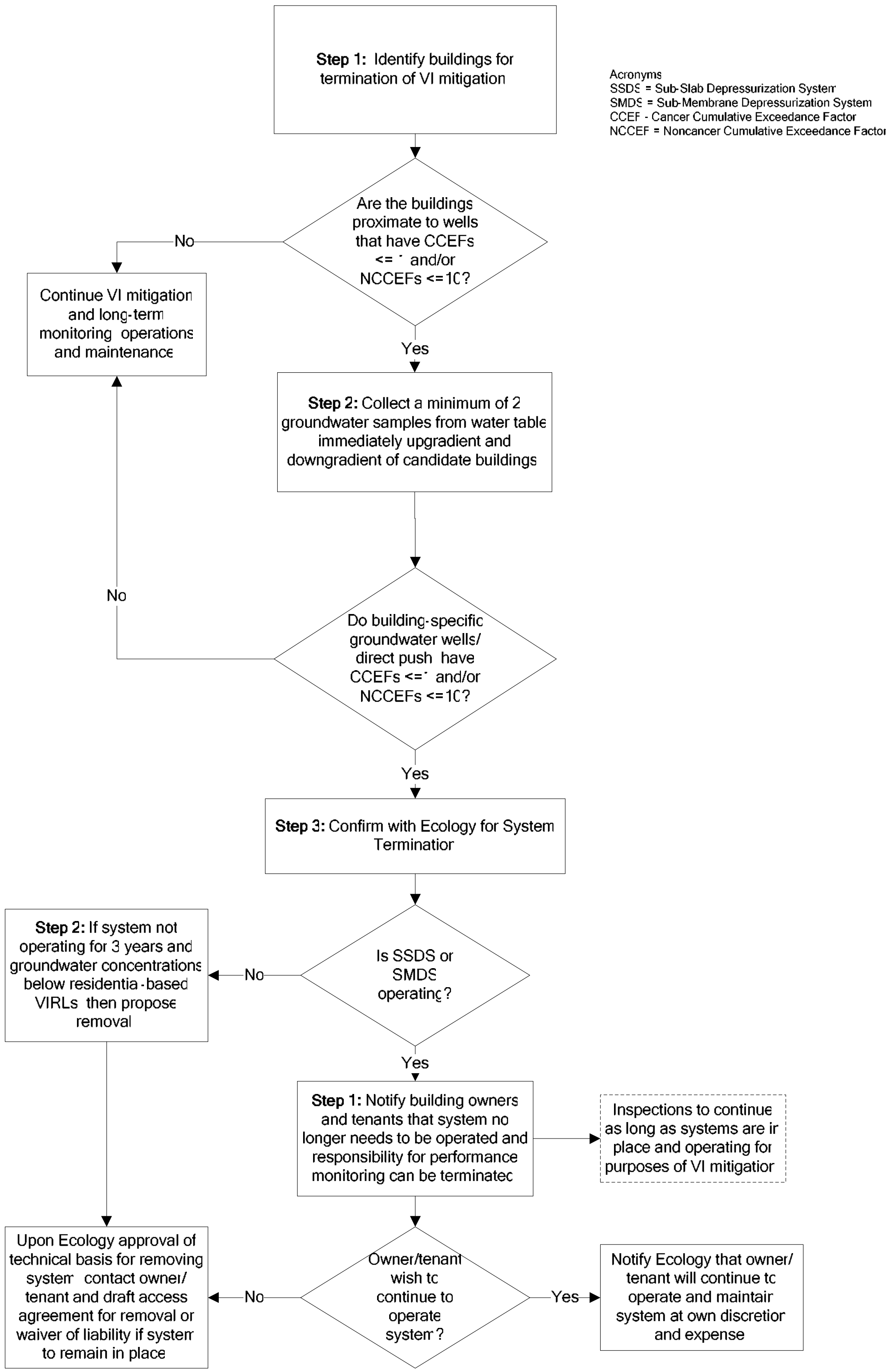
Figure 2-6

Figure 3-1 – VIAM Decision Tree



Acronyms:
SSDS = Sub-Slab Depressurization System
SMDS = Sub-Membrane Depressurization System

Figure 3-2 – Tier 5 of the VIAM Decision Tree



APPENDIX A

COMPARISON OF IPIMALS VERSUS ACTION LEVELS DEVELOPED USING THE JEM

A.1 INTRODUCTION AND OBJECTIVES

This appendix evaluates the methodology for predicting indoor air vapor intrusion (VI) from groundwater in the Georgetown community of Seattle, Washington by comparing Inhalation Pathway Interim Measure (IPIM) action levels (IPIMALs) that were calculated using the empirically-derived groundwater-to-indoor air volatilization factors (GIVFs) developed in IPIM Tech Memo 1 (PSC, 2003), to action levels calculated using GIVFs predicted by the Johnson and Ettinger Model (JEM). The area of concern is the Site Wide Feasibility Study (SWFS) Area (i.e., the area between the PSC Georgetown facility and 4th Avenue South) (see Figure 1-1 in the main document) at locations where concentrations of volatile organic constituents (VOCs) in shallow groundwater potentially exceed levels considered protective of human health established by the Washington State Department of Ecology (Ecology) for the inhalation pathway. PSC is conducting IPIMs to address this concern. The inhalation pathway is evaluated under the Washington State Model Toxics Control Act (MTCA), pursuant to Washington Administrative Code (WAC) 173-340-350, 173-340-720(1)(c), 173-340-720(1)(d)(iv), and 173-340-750.

GIVFs are used to predict indoor air concentrations from groundwater concentrations and are one of the input parameters used to calculate IPIMALs. GIVFs represent the volatilization of VOCs from groundwater into soil gas, migration of these VOCs through the vadose zone, and ultimately into buildings where the VOCs mix with indoor air. There are two different types of GIVFs used in this analysis:

- **Empirically-Based GIVFs** – One type of GIVF is derived using empirical data (Empirical GIVFs) as described by Tech Memo 1 (PSC, 2003). These GIVFs were developed by measuring groundwater and indoor air concentrations and calculating the ratio between the corrected indoor air concentration and the groundwater concentration. This process is described in Section 2.2.1 of the main document.
- **JEM-Based GIVFs** – The other type of GIVF is predicted by the JEM (JEM GIVFs), based on soil type and other parameters. The JEM is a one-dimensional analytical solution to diffusive and convective transport of vapors formulated as an attenuation factor that relates the vapor concentration in indoor air to the vapor concentration at the source (i.e., soil, groundwater or soil gas). The JEM can also be used to calculate a GIVF by predicting an indoor air concentration from a groundwater concentration and calculating the ratio between the two values.

The purpose of the analysis presented in this appendix is to compare IPIMALs, which are based on empirical GIVFs, with action levels based on JEM GIVFs . Two JEM GIVF scenarios were used for this comparison: 1) Loamy Sand, which is representative of site-specific conditions and 2) Sand, which is used to represent the maximum potential for VI.

A.2 MODEL OVERVIEW

The JEM was used in this analysis to develop JEM GIVFs representing the potential for VI from groundwater to indoor air (EQM, 2003). Since particle density, as it relates to soil properties and moisture content, is a factor that influences the rate of diffusion from groundwater to indoor air (Hers, 2002), two different soil types are considered in this analysis for modeling purposes. The United States Environmental Protection Agency (USEPA) JEM spreadsheet[1] and standard building-related default values that are recommended in Appendix G of the Office of Solid Waste and Emergency Response (OSWER) Draft VI Guidance Document (USEPA, 2002, EQM, 2003), were used in the analysis. Both Loamy Sand and Sand were analyzed, with Sand serving as a conservative value and Loamy Sand as a more realistic (i.e., site specific) indicator for estimating VI. See Table A-1 and Table A-2 for the complete list of specific parameters used in this analysis for Loamy Sand and Sand, respectively. All of the parameters used to develop JEM GIVFs for the Loamy Sand and Sand scenarios were identical except for the differences presented in Table A-1 and A-2.

A.3 EVALUATION PROCESS

Table A-3 presents a comparison of action levels based on the JEM GIVFs to IPIMALs that are based on Empirical GIVFs. IPIMALs, based on Empirical GIVFs, serve as a baseline for this analysis, since these were obtained from measured site-specific data. This data presented in Table A-3 indicates that:

- Action levels calculated based on the JEM GIVFs for Loamy Sand closely resemble the IPIMALs calculated based on Empirical GIVFs. The action levels calculated based on JEM GIVFs for Loamy Sand are within 20 percent of the IPIMALs.
- Action levels calculated based on JEM GIVFs for Sand are approximately five times lower (i.e., more protective) than the IPIMALs calculated based on Empirical GIVFs.

The impact of using action levels calculated based on JEM GIVFs versus IPIMALs calculated based on Empirical GIVFs in Tier 1 of the IPIM Decision Tree (see Figure 2-1 in the main document) was explored by comparing the potential Tier 3 footprint (i.e., the area of potential concern for VI from groundwater where building-specific VI sampling would take place) for each JEM GIVF scenario against the footprint developed using the IPIMALs. Groundwater data from monitoring wells and direct-push locations were evaluated for residential cancer-based groundwater IPIMALs at each location, according to the process described in Section 2.3.1 of the main document. Both 1st quarter 2006 (1Q06) groundwater monitoring data and previous monitoring data were included in the evaluation. Cancer exceedence factors (CEFs)[2] were calculated by dividing the measured groundwater concentration by its associated residential groundwater IPIMAL (or action level) for cancer. The individual CEFs were then added together at each location for individual constituents to obtain cumulative CEFs (CCEFs). The CCEFs were then plotted and contoured using an inverse distance weighting (IDW) interpolation to determine the potential Tier 3 footprint associated with each well or direct-push location (see Section 2.3.1 of the main document for more information on IDW). A comparison of the Tier 3 footprints for action levels calculated based on JEM GIVFs for Loamy Sand and IPIMALs is presented in Figure A-1. A comparison of the Tier 3

[1] USEPA spreadsheet GW-Adv-04.xls, Version 3.1; 02/04, (http://risk.lsd.ornl.gov/johnson_ettinger.html) was used for this evaluation.

[2] The results of the evaluation of Non-Cancer Cumulative Exceedence Factors (NCCEFs) were not presented in this appendix because they are co-located with the CCEFs.

footprints for action levels calculated based on JEM GIVFs for Sand and IPIMALs is presented in Figure A-2.

A.4 RESULTS

The action levels calculated based on the JEM GIVFs resulted in CCEFs that differed to a varying degree depending on the scenario (i.e., Loamy Sand or Sand) analyzed. When CCEFs based on JEM GIVFs for Loamy Sand were contoured, the potential Tier 3 footprint was very similar to the footprint generated using the IPIMALs (see Figure A-1). When CCEFs based on JEM GIVFs for Sand were contoured, it was evident that the potential Tier 3 footprint increased in comparison to the baseline Tier 3 footprint generated using the empirical GIVF IPIMALs (see Figure A-2).

Buildings that fall within the potential Tier 3 footprints generated by the Loamy Sand and Sand scenarios would be considered for evaluation under Tier 3 (site-specific sampling) or Tier 4 (VI mitigation). The data presented on Figures A-1 and A-2 indicates:

- If action levels calculated based on JEM GIVFs for Loamy Sand are used to calculate CCEFs, no new buildings would be considered candidates for Tier 3 or Tier 4 evaluation based on the potential Tier 3 footprint.
- If action levels calculated based on JEM GIVFs for Sand are used to calculate CCEFs, 10 additional buildings would be considered candidates for Tier 3 or Tier 4 evaluation based on the Tier 3 footprint. This is an overall increase in buildings of 8.5 percent.

The comparison between Empirical GIVF IPIMALs and JEM GIVF action levels using the site specific scenario (i.e., Loamy Sand), strongly supports the Empirical GIVFs that were used to develop the IPIMALs. The site-specific data used to develop the Empirical GIVFs result in IPIMALs that fall within the range of action levels calculated based on JEM GIVFs under similar site-specific conditions. This is consistent with geotechnical results, which have shown that Loamy Sand is representative of soil types within the Georgetown Area (PSC, 2003). In fact, the results of this analysis suggest that the Empirical GIVF IPIMAL approach is quite conservative, because the ultra-conservative JEM GIVF Sand scenario only identified 10 additional buildings as candidates for Tier 3. This is an increase of less than 10% (meaning that greater than 90% of the buildings identified as proceeding to Tier 3 under the JEM GIVF sand scenario were also identified for Tier 3 using the Empirical GIVF IPIMALs).

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Ecology. 2001. Washington State Department of Ecology. Model Toxics Control Act Cleanup Regulation. Chapter 173-340 Washington Administrative Code. Amended February 12, 2001. Publication Number 94-06.

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USEPA. 2002. U.S. Environmental Protection Agency. Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway. Office of Solid Waste and Emergency Response. Washington, D.C. EPA530-F-02-052. http://www.epa.gov/correctiveaction/eis/vapor.htm.

Table A-1. Summary of Input Parameters Used to Calculate JEM GIVF Action Levels for Groundwater Based on Protection of Indoor Air (Loamy Sand Scenario)

Parameter	Condition for Vapor Migration	Units	Reference
Average Soil/Groundwater Temperature (T_s)	15	^oC	Average temperature measured in field
Depth Below Grade to Bottom of Enclosed Floor Space (L_F)	200	cm	Default depth of average basement
Depth Below Grade to Water Table (L_{WT})	304.8	cm	Assumes water depth at 10 feet
Thickness of Soil Stratum (h_A)	304.8	cm	Assumes water depth at 10 feet
Soil Stratum Directly Above Water Table	A	--	Only one soil stratum was used for this analysis
SCS Soil Type Directly Above Water Table	Loamy Sand	--	Selected to represent site-specific conditions
Soil Vapor Permeability (k_v)	--	cm^2	Calculated based on loamy sand soil type
Stratum A Soil Dry Bulk Density ($\rho_b{}^A$)	1.62	g/cm^3	Default JEM value for loamy sand soil type
Stratum A Soil Total Porosity (n^A)	0.390	--	Default JEM value for loamy sand soil type
Stratum A Soil Water-Filled Porosity ($\theta_w{}^A$)	0.076	cm^3/cm^3	Default JEM value for loamy sand soil type
Enclosed Space Floor Thickness (L_{crack})	10	cm	Default JEM value for a residential building
Soil-Building Pressure Differential (ΔP)	40	$g/cm\text{-}s^2$	Default JEM value for a residential building
Enclosed Space Floor Length (L_B)	1000	cm	Default JEM value for a residential building
Enclosed Space Floor Width (W_B)	1000	cm	Default JEM value for a residential building
Enclosed Space Height (H_B)	366	cm	Default JEM value for a residential building
Floor-Wall Seam Crack Width (w)	0.1	cm	Default JEM value for a residential building
Indoor Air Exchange Rate (ER)	0.25	1/h	Default JEM value for a residential building
Average Vapor Flow Rate into Building (Q_{soil})	--	L/m	Calculated based on loamy sand soil type

Notes:

Standard default parameters applied, as recommended in USEPA spreadsheet (GW-Adv-Feb04.xls) and Appendix G of the OSWER Draft VI Guidance Document (USEPA, 2002).

Source: EPA's Johnson Ettinger Model (Version 3.1; 02/04).

-- = Units not applicable or value was calculated by model.

Table A-2. Summary of Input Parameters Used to Calculate JEM GIVF Action Levels for Groundwater Based on Protection of Indoor Air (Sand Scenario)

Parameter	Condition for Vapor Migration	Units	Reference
Average Soil/Groundwater Temperature (T_s)	15	^oC	Average temperature measured in field
Depth Below Grade to Bottom of Enclosed Floor Space (L_F)	200	cm	Default depth of average basement
Depth Below Grade to Water Table (L_{WT})	304.8	cm	Assumes water depth at 10 feet
Thickness of Soil Stratum (h_A)	304.8	cm	Assumes water depth at 10 feet
Soil Stratum Directly Above Water Table	A	--	Only one soil stratum was used for this analysis
SCS Soil Type Directly Above Water Table	Sand	--	Selected to represent site-specific conditions
Soil Vapor Permeability (k_v)	--	cm^2	Calculated based on sand soil type
Stratum A Soil Dry Bulk Density (ρ_b^A)	1.66	g/cm^3	Default JEM value for sand soil type
Stratum A Soil Total Porosity (n^A)	0.375	--	Default JEM value for sand soil type
Stratum A Soil Water-Filled Porosity (θ_w^A)	0.054	cm^3/cm^3	Default JEM value for sand soil type
Enclosed Space Floor Thickness (L_{crack})	10	cm	Default JEM value for a residential building
Soil-Building Pressure Differential (ΔP)	40	$g/cm\text{-}s^2$	Default JEM value for a residential building
Enclosed Space Floor Length (L_B)	1000	cm	Default JEM value for a residential building
Enclosed Space Floor Width (W_B)	1000	cm	Default JEM value for a residential building
Enclosed Space Height (H_B)	366	cm	Default JEM value for a residential building
Floor-Wall Seam Crack Width (w)	0.1	cm	Default JEM value for a residential building
Indoor Air Exchange Rate (ER)	0.25	1/h	Default JEM value for a residential building
Average Vapor Flow Rate into Building (Q_{soil})	--	L/m	Calculated based on sand soil type

Notes:

Standard default parameters applied, as recommended in USEPA spreadsheet (GW-Adv-Feb04.xls) and Appendix G of the OSWER Draft VI Guidance Document (USEPA, 2002).

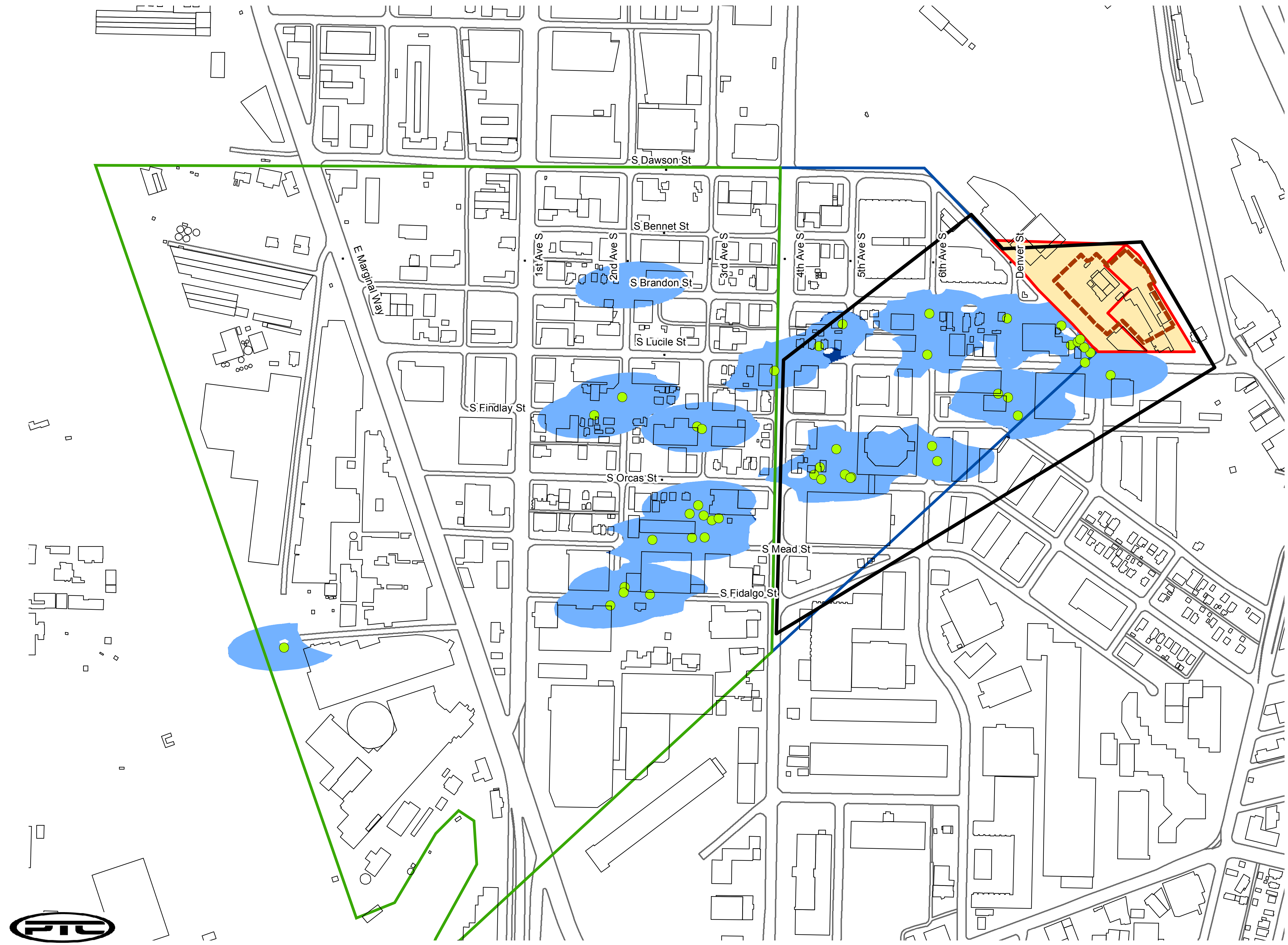
Source: EPA's Johnson Ettinger Model (Version 3.1; 02/04).

-- = Units not applicable or value was calculated by model.

Table A-3. Comparison of Empirical GIVF IPIMALs and JEM GIVF Action Levels Calculated Based on a Residential Scenario

Cas	Constituent	Empirical GIVF IPIMAL (ug/L)		JEM GIVF Action Level - Sand (ug/L)		JEM GIVF Action Level - Loamy Sand (ug/L)		Ratio of IPIMAL/JEM Action Level Sand		Ratio of IPIMAL/AJEM Action Level Loamy Sand	
		Noncancer	Cancer	Noncancer	Cancer	Noncancer	Cancer	Noncancer	Cancer	Noncancer	Cancer
71-55-6	1,1,1-trichloroethane	1094.9	--	208.8	--	918.8	--	5.2	--	1.2	--
75-34-3	1,1-dichloroethane	751.6	--	145.1	--	624.7	--	5.2	--	1.2	--
75-35-4	1,1-dichloroethylene	53.2	--	10.5	--	47.6	--	5.1	--	1.1	--
95-63-6	1,2,4-trimethylbenzene	13.0	--	2.3	--	9.5	--	5.7	--	1.4	--
107-06-2	1,2-dichloroethane	30.0	10.4	7.0	2.4	31.2	10.8	4.3	4.3	1.0	1.0
108-67-8	1,3,5-trimethylbenzene	9.8	--	2.4	--	10.0	--	4.0	--	1.0	--
591-78-6	2-hexanone	609.0	--	123.0	--	549.4	--	4.9	--	1.1	--
71-43-2	Benzene	41.1	7.8	8.3	1.6	36.9	7.0	5.0	5.0	1.1	1.1
75-00-3	Chloroethane	5437.4	--	931.0	--	5000.2	--	5.8	--	1.1	--
67-66-3	Chloroform	84.7	3.3	18.0	0.7	82.5	3.2	4.7	4.7	1.0	1.0
156-59-2	Cis-1,2-dichloroethylene	72.7	--	14.3	--	60.8	--	5.1	--	1.2	--
100-41-4	Ethylbenzene	1262.4	--	241.4	--	1048.2	--	5.2	--	1.2	--
91-20-3	Naphthalene	59.2	--	15.1	--	53.8	--	3.9	--	1.1	--
99-87-6	P-isopropyltoluene	74.9	--	15.1	--	67.6	--	4.9	--	1.1	--
103-65-1	Propylbenzene	26.9	--	7.7	--	32.2	--	3.5	--	0.8	--
135-98-8	Sec-butylbenzene	23.1	--	1142.1	--	4129.2	--	0.02	--	0.01	--
127-18-4	Tetrachloroethylene	326.9	4.0	61.0	0.8	264.8	3.3	5.4	5.4	1.2	1.2
108-88-3	Toluene	496.1	--	98.8	--	440.5	--	5.0	--	1.1	--
156-60-5	Trans-1,2-dichloroethylene	65.3	--	12.3	--	52.9	--	5.3	--	1.2	--
79-01-6	Trichloroethylene	29.6	0.4	5.7	0.1	25.1	0.3	5.2	5.6	1.2	1.3
75-01-4	Vinyl Chloride	20.6	1.0	4.3	0.2	19.9	1.0	4.8	4.8	1.0	1.0

Notes:
-- = No value. No toxicity information was available to calculate an IPIMAL.
Empirical GIVF IPIMAL = Inhalation Pathway Interim Measure Action Level developed using empirical Groundwater-to-Indoor Air Volatilization Factors.
Predicted GIVF Action Levels – Action Levels developed using GIVF predicted by the JEM.
JEM = The USEPA's Johnson and Ettinger Model. GW-ADV Version 3.1; 02/04.
The IPIMALs were developed based on a Residential Exposure Scenario using the following target risk goals for individual constituents:
- Cancer Risk (CR) = 1E-06.
- Hazard Quotient (HQ)= 0.1.
Noncancer = Noncancer-Based IPIMAL or Action Level.
Cancer = Cancer-Based IPIMAL or Action Level.



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Legend

- Roads
- Buildings
- Site Wide Feasibility Study Area
- HCIM Area
- Areas 1 and 2
- Area 3
- Comingled Plume Area
- Footprint for IPIMALs - CCEFs > 10*
- Footprint for JEM-based Action Levels (loamy sand) CCEFs > 10**

Residential CCEFs

- >10 CCEF

0 150 300 600 900 Feet

Notes

IPIMALS and JEM-based action levels were compared to 1Q06 and previous groundwater monitoring results to calculate residential CCEFs.

* IPIMALs developed using GIVF approach outlined in Tech Memo 1.

** Footprint for action levels calculated with GIVFs developed using the JEM and loamy sand soil scenario.

- IPIMALs for groundwater are based on a carcinogenic risk of 1E-6 and Hazard Quotient of 0.1.

- Areas 1, 2, and 3 were designated in the Final Risk Assessment (PSC, 2003).

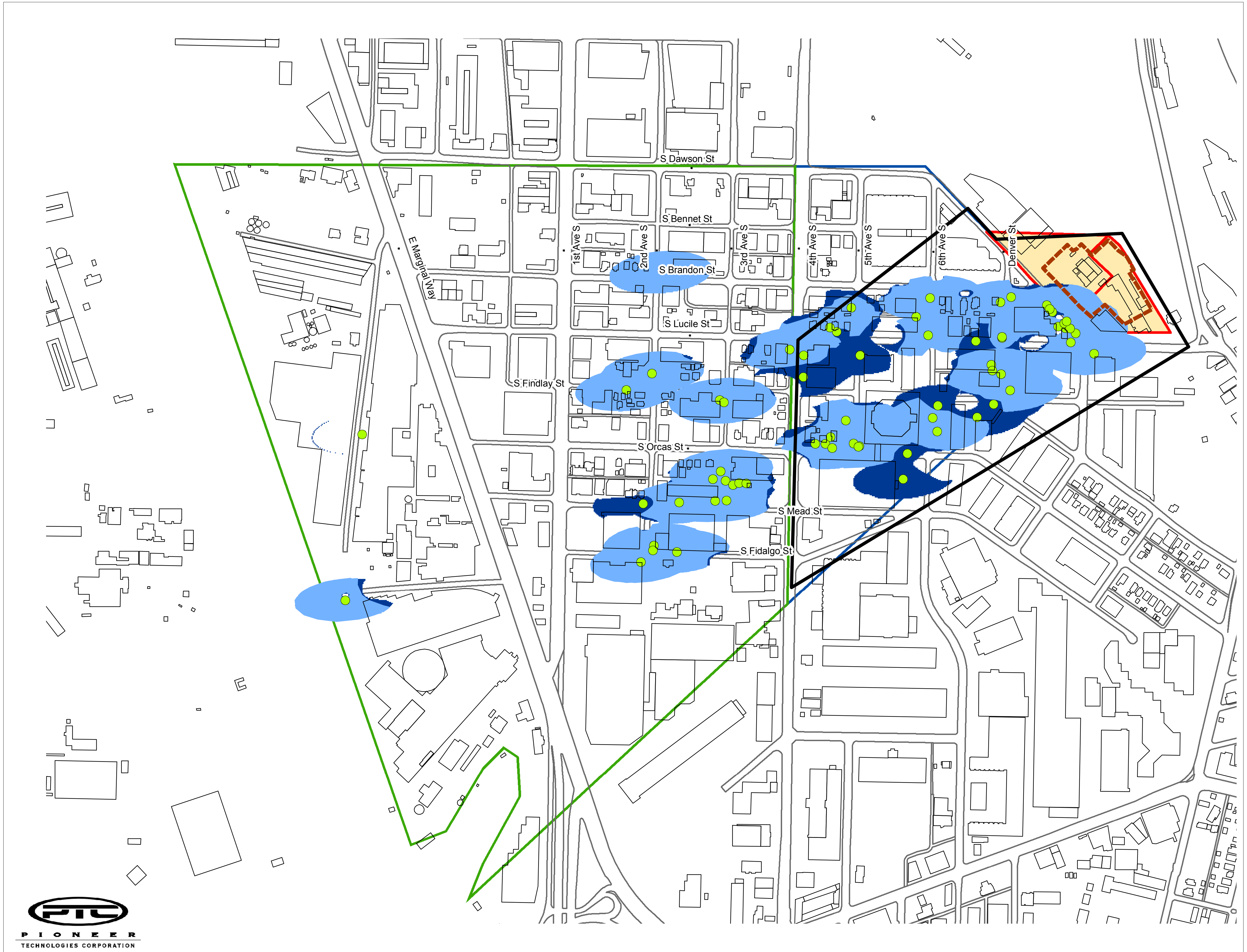
HCIM -- Hydraulic Control Interim Measure

Tier 1 Residential CCEFs for COPCs Detected in Groundwater

Loamy Sand Soil

PSC Georgetown
May 2006

Figure A-1



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Legend

- Roads
- Buildings
- Site Wide Feasibility Study Area
- HCIM Area
- Areas 1 and 2
- Area 3
- Comingled Plume Area
- Footprint for IPIMALs - CCEFs > 10*
- Footprint for JEM-based Action Levels (sand) CCEFs > 10**

Residential CCEFs

- >10 CCEF

0 150 300 600 900
Feet

Notes

IPIMALS and JEM-based action levels were compared to 1Q06 and previous groundwater monitoring results to calculate residential CCEFs.

* IPIMALs developed using GIVF approach outlined in Tech Memo 1.

** Footprint for action levels calculated with GIVFs developed using the JEM and sand soil scenario.

- IPIMALs for groundwater are based on a carcinogenic risk of 1E-6 and Hazard Quotient of 0.1.

- Areas 1, 2, and 3 were designated in the Final Risk Assessment (PSC, 2003).

HCIM -- Hydraulic Control Interim Measure

Tier 1 Residential CCEFs for COPCs Detected in Groundwater
Sandy Soil

PSC Georgetown
May 2006

Figure A-2

APPENDIX B

IMPACT OF CORRECTING INDOOR AIR CONCENTRATIONS USING AMBIENT AIR CONCENTRATIONS ON DECISIONS MADE IN TIER 3 OF THE IPIM DECISION TREE

B.1 INTRODUCTION

The purpose of this appendix is to assess the impact on the decisions made as the result of Tier 3 evaluations performed under the Inhalation Pathway Interim Measures (IPIM) Decision Tree (see Figure B-1) of using "corrected" indoor air concentrations by subtracting ambient air concentrations. This appendix focuses on locations where Tier 3 evaluations were performed and the results indicated that indoor air concentrations were below the Washington State Department of Ecology's (Ecology's) health benchmarks. Consequently, these locations did not proceed to Tier 4 (i.e., installation of a vapor intrusion [VI] mitigation system) but returned to Tier 1/Tier 2 (i.e., continued monitoring of groundwater).

B.2 SENSITIVITY ANALYSIS PROCESS

Eighteen properties were re-evaluated in this appendix using an approach identical to the original Tier 3 evaluations except the indoor air concentrations were not "corrected" for background by subtracting ambient air. That is, the uncorrected indoor air concentrations were compared directly to indoor air IPIM Action Levels (IPIMALs[1]) to determine if Ecology's risk benchmarks were exceeded and these properties would have proceeded to Tier 4. The 18 properties evaluated in this analysis are presented in Figure B-2. These properties were selected for this evaluation because they were evaluated under Tier 3 of the IPIM Decision Tree and did not proceed to Tier 4. For both "corrected" and "uncorrected" indoor air, noncancer exceedance factors (NCEFs) were calculated by dividing the indoor air concentrations by noncancer-based indoor air IPIMALs. Cancer exceedance factors (CEFs) were calculated by dividing the indoor air concentrations by cancer-based indoor air IPIMALs. The individual NCEFs and CEFs were summed to provide the cumulative NCEFs (i.e., NCCEFs) and cumulative CEFs (i.e., CCEFs). Please note that, per the Revised IPIM Work Plan (PSC, 2002), NCCEFs and CCEFs were only calculated for constituents detected in both groundwater and indoor air.

B.3 RESULTS OF THE SENSITIVITY ANALYSIS

NCCEFs and CCEFs for 18 locations that were re-evaluated using uncorrected indoor air are presented in Table B-1. If either the NCCEF or CCEF exceeded Ecology's health benchmarks of 10, then those locations were re-classified as Tier 4 locations. Ten of the 18 locations were not re-classified (i.e., after being re-evaluated under Tier 3 the conclusion was the same as the original Tier 3 evaluation) because the

[1] The IPIMALs were recalculated using the most current toxicity information in April 2005.

uncorrected indoor air concentrations were below risk benchmarks. These locations would not proceed to Tier 4 but would be re-evaluated during the next round of quarterly groundwater monitoring. Eight of the locations (44 percent) originally evaluated under Tier 3 and determined not to require VI mitigation would be identified as requiring VI mitigation as the result of not correcting for background by subtracting ambient air concentrations from indoor air concentrations prior to comparing the indoor air concentration to the IPIMALs.

For the eight reclassified locations, an additional evaluation was performed. Indoor air concentrations for the eight locations were modeled by multiplying the maximum detected groundwater concentrations by the chemical-specific groundwater-to-indoor air volatilization factor (GIVF) (modeled indoor air). Each modeled indoor air concentration was compared to the measured maximum indoor air concentration (measured indoor air) to determine if the measured indoor air concentrations are indicative of concentrations associated with volatilization from groundwater. Locations where the measured indoor air concentration is significantly higher than the modeled indoor air concentration may reflect indoor air and/or ambient air background sources that are contributing to the measured indoor air concentration.

B.3.1 Detailed Information on Re-Classified Locations

This section presents additional data for the eight locations that would be re-classified to Tier 4 based on the Tier 3 evaluation of the uncorrected indoor air data. NCCEFs and CCEFs calculated using corrected indoor air concentrations (corrected Tier 3) are compared with NCCEFs and CCEFs calculated using uncorrected indoor air concentrations (uncorrected Tier 3). In addition, the indoor air concentration predicted by multiplying the groundwater concentration by the GIVF (modeled indoor air concentration) was compared with the uncorrected indoor air concentration (maximum detected indoor air concentration) for each location. Detailed site-specific information for each building is provided in Tables B-2 through B-9.

B.3.1.1 5327 Denver Avenue South

5327 Denver Aveue South is a residential building that was evaluated in August 2002 (PSC, 2002). The NCCEF and CCEF calculated in the original Tier 3 evaluation were 0 because the ambient air concentrations were greater than the indoor air concentrations. The NCCEF and CCEF calculated based on uncorrected indoor air concentrations were 1.6 and 25.9, respectively.

Benzene and trichloroethylene (TCE) were the only constituents contributing to the NCCEF and CCEF in the uncorrected Tier 3 evaluation (see Table B-2). The modeled indoor air concentration for benzene (0.04 ug/m^3) was significantly lower than the maximum detected indoor air concentration (1.8 ug/m^3). The modeled indoor air concentration for TCE (0.004 ug/m^3) was significantly lower than the maximum detected indoor air concentration (0.38 ug/m^3).

B.3.1.2 508 South Mead

508 South Mead is a commercial building, referred to by the mailing address, 5701 6th Avenue South in the Tier 3 Report (PSC, 2004a). The NCCEF calculated in the original Tier 3 evaluation was 0.02. The CCEF was not calculated in the original Tier 3 evaluation because the TCE concentration in ambient air (29 ug/m^3) was higher than the indoor air concentration (27 ug/m^3). The NCCEF and CCEF calculated based on uncorrected indoor air concentrations were 4.9 and 545.2, respectively.

TCE concentrations contributed to the majority of the CCEF in the uncorrected Tier 3 (see Table B-3). The modeled indoor air concentration for TCE (2.5 ug/m^3) was significantly lower than the measured indoor air concentration (27 ug/m^3).

B.3.1.3 500 South Lucile

500 South Lucile is a commercial building, referred to by the mailing address, 580 South Lucile Street in the Tier 3 Report (PSC, 2004b). The NCCEF and CCEF calculated in the original Tier 3 evaluation were 0.05 and 6.4, respectively. The NCCEF and CCEF calculated based on uncorrected indoor air concentrations were 0.15 and 20.0, respectively.

TCE was the only constituent with concentrations contributing to the NCCEF and CCEF calculated in both the corrected and uncorrected Tier 3 evaluations (see Table B-4). The modeled indoor air concentration for TCE (0.01 ug/m^3) was significantly lower than the measured indoor air concentration (1.0 ug/m^3).

B.3.1.4 5600 6th Avenue South

5600 6th Avenue South is a commercial building and is also referred to as 5600 – 5620 6th Avenue South in the Tier 3 Report (February 2004c). The NCCEF and CCEF calculated in the original Tier 3 evaluation were 0.04 and 4.9, respectively. The NCCEF and CCEF calculated based on uncorrected indoor air concentrations were 0.1, and 13.8, respectively.

TCE concentrations contributed to the majority of the NCCEF and CCEF in both the corrected and uncorrected Tier 3 evaluations (see Table B-5). The modeled indoor air concentration for TCE (0.62 ug/m^3) was similar to the measured indoor air concentration (0.06 ug/m^3) at this location.

B.3.1.5 5606 2nd Avenue South

5606 2nd Avenue South is a residential building (PSC, 2005). There were no NCCEF or CCEF calculated in the original Tier 3 evaluation because the ambient air concentration for TCE (0.2 ug/m^3) was greater than the indoor air concentration (0.15 ug/m^3) and the ambient air concentration for benzene (3.4 ug/m^3) was greater than the indoor air concentration (0.98 ug/m^3). The NCCEF and CCEF calculated based on uncorrected indoor air concentrations were 1.1, and 11.3, respectively.

TCE concentrations contributed to the majority of the CCEF in the uncorrected Tier 3 evaluation (see Table B-6). The modeled indoor air concentration for TCE (0.01 ug/m^3) was significantly lower than the measured indoor air concentration (0.15 ug/m^3). The modeled indoor air concentration for benzene (0.32 ug/m^3) was approximately three times lower than the measured indoor air concentration (0.98 ug/m^3).

B.3.1.6 5610 2nd Avenue South

5610 2nd Avenue South is a residential building (PSC, 2005). The NCCEF in the original Tier 3 evaluation was 0.1. No CCEF was calculated in the original Tier 3 evaluation because the ambient air concentration for TCE (0.2 ug/m^3) was greater than the indoor air concentration (0.14 ug/m^3) and the ambient air concentration for benzene (3.4 ug/m^3) was greater than the indoor air concentration (0.92

ug/m^3). The NCCEF and CCEF calculated based on uncorrected indoor air concentrations evaluation were 1.4 ug/m^3, and 10.6 ug/m^3, respectively.

Benzene and TCE concentrations were the primary contributors to the CCEF in the uncorrected Tier 3 (see Table B-7). The modeled indoor air concentration for TCE (0.01 ug/m^3) was significantly lower than the measured indoor air concentration (0.14 ug/m^3). The modeled indoor air concentration for benzene (0.32 ug/m^3) was approximately three times lower than the measured indoor air concentration (0.92 ug/m^3).

B.3.1.7 5706 2nd Avenue South

5706 2nd Avenue South is a commercial building (PSC, 2004d). The NCCEF and CCEF calculated in the original Tier 3 evaluation were 0.1 and 7.8, respectively. The NCCEF and CCEF calculated based on uncorrected indoor air concentration were 0.1 and 15.7, respectively. TCE was the only constituent with concentrations contributing to the NCCEF and CCEF in both corrected and uncorrected Tier 3 evaluations (see Table B-8). The modeled indoor air concentration for TCE (0.005 ug/m^3) was significantly lower than the measured indoor air concentration (0.8 ug/m^3).

B.3.1.8 665 South Lucile Street

665 South Lucile Street is a commercial building, referred to by the mailing address, 637 South Lucile Street in the Tier 3 Report (PSC, 2004e). This location was sampled initially in November 2003 and re-sampled in August 2005. The NCCEF and CCEF calculated in the original Tier 3 (November 2003) evaluation were 0.06 and 8.8, respectively. The NCCEF and CCEF calculated based on uncorrected (November 2003) indoor air concentrations were 0.13 and 17.4, respectively.

TCE concentrations contributed to the majority of the NCCEF and CCEF in both the corrected and uncorrected Tier 3 evaluations (see Table B-9). The modeled indoor air concentration for TCE (1.2 ug/m^3) was similar to the measured indoor air concentration (0.84 ug/m^3) at this location.

B.4 CONCLUSIONS

In summary, a total of 18 Tier 3 locations did not proceed to Tier 4 under the IPIM program after the site-specific VI assessments were completed because these locations had indoor air concentrations (corrected by subtracting the ambient air concentrations from indoor air concentrations), associated with VI from groundwater, below Ecology's risk threshold. These buildings were re-evaluated using uncorrected indoor air concentrations to determine whether or not any of the buildings would be re-classified as requiring VI mitigation (i.e., proceed to Tier 4). Following this re-analysis using the uncorrected indoor air concentration, the status for 10 of the 18 buildings remained unchanged (i.e., these buildings moved back to Tier 1 and Tier 2 monitoring just as the results of the original Tier 3 analysis indicated). However, eight buildings (three residential and five commercial) were re-classified as requiring VI mitigation (i.e., proceed to Tier 4).

These buildings were further evaluated by comparing modeled indoor air concentrations (calculated by multiplying the groundwater concentration by the chemical-specific GIVF) to measured (uncorrected) indoor air concentrations. In most cases, the modeled indoor air concentrations were significantly lower than the measured concentrations, indicating that background sources are contributing to measured indoor air concentrations. At one location (665 South Lucile Street), modeled indoor air concentrations were higher than measured values. These are commercial buildings and there is more uncertainty associated with the GIVFs as they relate to commercial buildings because the GIVFs are based on empirical data from residential buildings and more likely to over-predict concentrations in indoor air in commercial buildings.

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Philip Services Corporation (PSC). 2002. Revised Inhalation Pathway Interim Measures Work Plan, August 12, 2002 and Errata Document, September 17, 2002.

Table B-1 – Comparison of Tier 3 Decisions When Indoor Air Concentrations Are Corrected and Are Not Corrected for Background

Tier-3 Location	Property Type	Status After Re-Evaluation Using Uncorrected Indoor Air Concentrations	COPCs Detected in Groundwater and Indoor Air With Corrected Indoor Air Concentrations (i.e., Indoor Air – Ambient Air)		COPCs Detected in Groundwater and Indoor Air With Uncorrected Indoor Air Concentrations	
			NCCEFs	CCEFs	NCCEFs	CCEFs
308 South Orcas Street	Commercial	Unchanged: Return to Tier 2	--	--	--	--
5327 Denver Avenue South	Residential	Move to Tier 4	--	--	1.6	25.9
508 South Mead	Commercial	Move to Tier 4	0.02	--	4.9	545.2
500 South Lucile	Commercial	Move to Tier 4	0.05	6.4	0.15	20
507 S Brandon Street	Residential	Unchanged: Return to Tier 1	--	--	--	--
519 Brandon Street	Commercial	Unchanged: Return to Tier 2	--	--	--	--
527 South Lucile	Commercial	Unchanged: Return to Tier 2	--	--	0.006	0.7
5412 6th Avenue South	Commercial	Unchanged: Return to Tier 2	0.003	0.4	0.003	0.4
5413 Maynard Avenue South	Commercial	Unchanged: Return to Tier 2	0.02	0.1	0.4	2.9
5506 6th Avenue South	Commercial	Unchanged: Return to Tier 2	0.07	--	0.6	6.1
5600 6th Avenue South	Commercial	Move to Tier 4	0.04	4.9	0.1	13.8
5602 2nd Avenue South	Residential	Unchanged: Return to Tier 1	--	--	--	--
5606 2nd Avenue South	Residential	Move to Tier 4	--	--	1.1	11.3
5610 2nd Avenue South	Residential	Move to Tier 4	0.1	--	1.4	10.6
5706 2nd Avenue South	Commercial	Move to Tier 4	0.1	7.8	0.1	15.7
612 South Orcas	Commercial	Unchanged: Return to Tier 2	--	--	0.006	0.8
650 South Lucile	Commercial	Unchanged: Return to Tier 2	0.2	2.5	2.1	9.5
665 South Lucile	Commercial	Move to Tier 4	0.06	8.8	0.13	17.4

Notes:
-- -- The NCCEF or CCEF was 0
COPC -- Constituent of Potential Concern
CCEFs – Cancer Cumulative Exceedance Factors
NCCEFs – Noncancer Cumulative Exceedance Factors

Table B-2 – Tier 3 Re-Evaluation for 5327 Denver Avenue South
Building Type: Residential

	Residential Groundwater IPIMAL		Residential Air IPIMAL		Maximum Detected Groundwater Concentration	Maximum Detected Soil-Gas Concentration	Groundwater to Indoor Air VF	Modeled Indoor Air Concentration Based on Groundwater Using GIVFs[1]	Maximum Detected Indoor Air Concentration	Maximum Detected Ambient Air Concentration	Corrected Indoor Air Concentration (IA - AA)
	Noncancer	Cancer	Noncancer	Cancer							
COPC	ug/L	ug/L	ug/m^3	ug/m^3	ug/L	ug/m^3	ug/m^3 / ug/L	ug/m^3	ug/m^3	ug/m^3	ug/m^3
1,1,1,2-Tetrachloroethane	--	--	--	--	--	--	--	--	--	--	--
1,1,1-Trichloroethane	1094.95	--	100.80	--	--	0.83	0.09	--	0.31	--	0.31
1,1,2-Trichloroethane	--	--	--	--	--	--	0.01	--	--	--	--
1,1,2-Trichlorotrifluoroethane	1208.76	--	1371.43	--	--	--	1.13	--	--	--	--
1,1-Dichloroethane	751.57	--	22.86	--	3.11	2.70	0.03	0.09	--	--	--
1,1-Dichloroethylene	53.21	--	9.14	--	--	--	0.17	--	--	--	--
1,2,4-Trimethylbenzene	13.01	--	0.27	--	--	9.40	0.02	--	3.20	2.10	1.10
1,2-Dichlorobenzene	1118.80	--	9.14	--	--	--	0.01	--	--	--	--
1,2-Dichloroethane	30.01	10.41	0.22	0.08	--	--	0.01	--	0.21	--	0.21
1,2-Dichloropropane	--	--	--	--	--	--	--	--	--	--	--
1,3,5-Trimethylbenzene	9.76	--	0.27	--	--	2.10	0.03	--	1.00	0.71	0.29
1,3-Dichlorobenzene	--	--	--	--	--	--	--	--	--	--	--
1,4-Dichlorobenzene	--	--	36.57	--	--	--	--	--	--	--	--
2-Chloroethylvinyl ether	--	--	--	--	--	--	0.0003	--	--	--	--
2-Hexanone	608.98	--	0.80	--	--	5.70	0.0013	--	--	2.00	--
Acetone	--	--	--	--	--	--	0.0008	--	--	--	--
Benzene	41.06	7.76	1.37	0.26	1.32	2.90	0.03	0.04	1.80	1.80	--
Bromodichloromethane	--	--	--	--	--	--	--	--	--	--	--
Bromoform	--	--	--	--	--	--	--	--	--	--	--
Bromomethane	--	--	--	--	--	--	--	--	--	--	--
Carbon disulfide	--	--	32.00	--	--	--	0.22	--	--	--	--
Carbon tetrachloride	--	--	--	0.13	--	--	0.16	--	--	--	--
Chlorobenzene	--	--	0.91	--	--	--	--	--	--	--	--
Chloroethane	5437.44	--	457.14	--	--	--	0.08	--	--	--	--
Chloroform	84.65	3.32	2.24	0.09	--	1.40	0.03	--	--	--	--
Chloromethane	--	--	--	--	--	--	--	--	--	--	--
Cumene	74.90	--	18.29	--	--	--	0.24	--	--	--	--
Dibromochloromethane	--	--	--	--	--	--	--	--	--	--	--
Ethylbenzene	1262.40	--	45.71	--	--	3.70	--	--	0.91	0.99	--
Methyl ethyl ketone	--	--	--	--	--	--	--	--	--	--	--
Methyl isobutyl ketone (MIBK)	104397.30	--	137.14	--	--	--	--	--	--	--	--
Methylene chloride	8284.80	259.66	137.14	4.30	--	--	0.02	--	--	--	--
Naphthalene	59.16	--	0.14	--	--	--	0.002	--	--	--	--
Propylbenzene	26.87	--	1.60	--	--	--	--	--	--	--	--
Styrene	--	--	45.71	--	--	--	--	--	--	--	--
Tetrachloroethylene (PCE)	326.86	4.05	27.20	0.34	--	3.60	--	--	0.28	0.41	--
Toluene	496.13	--	18.29	--	--	9.40	--	--	7.80	7.40	0.40
Trichloroethylene	29.57	0.40	1.60	0.02	0.07	0.89	0.05	0.004	0.38	0.41	--
Trichlorofluoromethane (TCE)	--	--	--	--	--	--	0.38	--	--	--	--
Vinyl acetate	--	--	--	--	--	--	--	--	--	--	--

Table B-2 – Tier 3 Re-Evaluation for 5327 Denver Avenue South
Building Type: Residential

COPC	Residential Groundwater IPIMAL		Residential Air IPIMAL		Maximum Detected Groundwater Concentration	Maximum Detected Soil-Gas Concentration	Groundwater to Indoor Air VF	Modeled Indoor Air Concentration Based on Groundwater Using GIVFs[1]	Maximum Detected Indoor Air Concentration	Maximum Detected Ambient Air Concentration	Corrected Indoor Air Concentration (IA - AA)
	Noncancer	Cancer	Noncancer	Cancer							
	ug/L	ug/L	ug/m^3	ug/m^3	ug/L	ug/m^3	ug/m^3 / ug/L	ug/m^3	ug/m^3	ug/m^3	ug/m^3
Vinyl chloride	20.62	1.04	4.57	0.23	0.21	0.23	0.22	0.05	--	0.43	--
cis-1,2-Dichloroethylene	72.71	--	1.60	--	--	1.80	--	--	--	--	--
cis-1,3-Dichloropropene	--	--	--	--	--	--	--	--	--	--	--
m,p-Xylenes	--	--	--	--	--	--	--	--	--	--	--
o-Xylene	--	--	--	--	--	--	--	--	--	--	--
p-Isopropyltoluene	74.90	--	18.29	--	--	--	0.24	--	--	--	--
sec-Butylbenzene	23.14	--	1.60	--	--	--	--	--	--	--	--
trans-1,2-Dichloroethylene	65.26	--	3.20	--	--	--	--	--	--	--	--
trans-1,3-Dichloropropene	--	--	--	--	--	--	--	--	--	--	--

Notes:
Only detected values are presented.
-- = An IPIMAL was not calculated because there was no toxicity value available. Or, the COPC was not detected.
IPIMAL = Inhalation Pathway Interim Measure Action Level
The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:
Cancer Risk (CR) = 1E-06
Hazard Quotient (HQ) = 0.1
Noncancer = Noncancer-Based IPIMAL
Cancer = Cancer-Based IPIMAL
IA = Indoor Air
AA = Ambient Air
[1]Modeled Indoor Air Concentration = (Maximum Detected Groundwater Concentration) x (Groundwater-to-Indoor Air Volatilzation Factor [GIVF])

Table B-2 – Tier 3 Re-Evaluation for 5327 Denver Avenue South
Building Type: Residential

COPC	COPC Detected in Groundwater and Indoor Air			
	With Corrected Indoor Air Concentration (IA-AA)		With Uncorrected Indoor Air Concentration	
	Commercial Noncancer Exceedance Factor	Commercial Cancer Exceedance Factor	Commercial Noncancer Exceedance Factor	Commercial Cancer Exceedance Factor
	NCEF	CEF	NCEF	CEF
1,1,1,2-Tetrachloroethane	--	--	--	--
1,1,1-Trichloroethane	--	--	--	--
1,1,2-Trichloroethane	--	--	--	--
1,1,2-Trichlorotrifluoroethane	--	--	--	--
1,1-Dichloroethane	--	--	--	--
1,1-Dichloroethylene	--	--	--	--
1,2,4-Trimethylbenzene	--	--	--	--
1,2-Dichlorobenzene	--	--	--	--
1,2-Dichloroethane	--	--	--	--
1,2-Dichloropropane	--	--	--	--
1,3,5-Trimethylbenzene	--	--	--	--
1,3-Dichlorobenzene	--	--	--	--
1,4-Dichlorobenzene	--	--	--	--
2-Chloroethylvinyl ether	--	--	--	--
2-Hexanone	--	--	--	--
Acetone	--	--	--	--
Benzene	--	--	1.31	6.95
Bromodichloromethane	--	--	--	--
Bromoform	--	--	--	--
Bromomethane	--	--	--	--
Carbon disulfide	--	--	--	--
Carbon tetrachloride	--	--	--	--
Chlorobenzene	--	--	--	--
Chloroethane	--	--	--	--
Chloroform	--	--	--	--
Chloromethane	--	--	--	--
Cumene	--	--	--	--
Dibromochloromethane	--	--	--	--
Ethylbenzene	--	--	--	--
Methyl ethyl ketone	--	--	--	--
Methyl isobutyl ketone (MIBK)	--	--	--	--
Methylene chloride	--	--	--	--
Naphthalene	--	--	--	--
Propylbenzene	--	--	--	--
Styrene	--	--	--	--
Tetrachloroethylene	--	--	--	--
Toluene	--	--	--	--
Trichloroethylene	--	--	0.24	19.0
Trichlorofluoromethane	--	--	--	--
Vinyl acetate	--	--	--	--

Table B-2 – Tier 3 Re-Evaluation for 5327 Denver Avenue South
Building Type: Residential

	COPC Detected in Groundwater and Indoor Air			
	With Corrected Indoor Air Concentration (IA-AA)		With Uncorrected Indoor Air Concentration	
	Commercial Noncancer Exceedance Factor	Commercial Cancer Exceedance Factor	Commercial Noncancer Exceedance Factor	Commercial Cancer Exceedance Factor
COPC	**NCEF**	**CEF**	**NCEF**	**CEF**
Vinyl chloride	--	--	--	--
cis-1,2-Dichloroethylene	--	--	--	--
cis-1,3-Dichloropropene	--	--	--	--
m,p-Xylenes	--	--	--	--
o-Xylene	--	--	--	--
p-Isopropyltoluene	--	--	--	--
sec-Butylbenzene	--	--	--	--
trans-1,2-Dichloroethylene	--	--	--	--
trans-1,3-Dichloropropene	--	--	--	--
Total:	**--**	**--**	**1.55**	**25.9**

Notes:

-- = Not calculated. NCEFs and CEFs were only calculated for COPCs that exhibited a complete exposure pathway for the groundwater to indoor air vapor intrusion pathway (i.e. the COPC was detected in groundwater and indoor air).

IPIMAL = Inhalation Pathway Interim Measure Action Level

The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:

Cancer Risk (CR) = 1E-06

Hazard Quotient (HQ) = 0.1

Noncancer = Noncancer-Based IPIMAL

Cancer = Cancer-Based IPIMAL

IA = Indoor Air

AA = Ambient Air

NCEF = Noncancer exceedance factor = Indoor Air Concentration / Noncancer IPIMAL

CEF = Cancer exceedance factor = Indoor Air Concentration / Cancer IPIMAL

Table B-3 – Tier 3 Re-Evaluation for 508 South Mead (Design Center)
Building Type: Commercial

COPC	Commercial Groundwater IPIMAL		Commercial Air IPIMAL		Maximum Detected Groundwater Concentration	Maximum Detected Soil-Gas Concentration	Groundwater to Indoor Air VF	Modeled Indoor Air Concentration Based on Groundwater Using GIVFs[1]	Maximum Detected Indoor Air Concentration	Maximum Detected Ambient Air Concentration	Corrected Indoor Air Concentration (IA - AA)
	Noncancer	Cancer	Noncancer	Cancer							
	ug/L	ug/L	ug/m^3	ug/m^3	ug/L	ug/m^3	ug/m^3 / ug/L	ug/m^3	ug/m^3	ug/m^3	ug/m^3
1,1,1-Trichloroethane	4662.64	--	429.24	--	--	1.3	0.09	--	0.47	0.34	0.13
1,1-Dichloroethane	3200.44	--	97.33	--	33	--	0.03	1.0	--	--	--
1,1-Dichloroethylene	226.57	--	38.93	--	3.84	--	0.17	0.7	0.22	--	0.22
1,2,4-Trimethylbenzene	55.42	--	1.16	--	--	2.3	0.02	--	3.2	6	--
1,2-Dichloroethane	127.80	30.09	0.95	0.2	1.45	8.1	0.01	0.01	0.44	1.4	--
1,3,5-Trimethylbenzene	41.57	--	1.16	--	--	0.54	0.03	--	0.95	1.8	--
2-Hexanone	2593.26	--	3.41	--	--	--	0.001	--	--	--	--
Benzene	174.86	22.42	5.84	0.75	2.71	2.5	0.03	0.1	2.4	3.7	--
Chloroethane	23154.44	--	1946.67	--	--	1.3	0.08	--	--	--	--
Chloroform	22.14	9.60	0.59	0.25	--	11	0.03	--	0.28	0.38	--
Ethylbenzene	5375.74	--	194.67	--	--	0.77	0.04	--	6.3	9.7	--
Naphthalene	251.91	--	0.58	--	--	--	0.002	--	--	--	--
Propylbenzene	114.40	--	6.81	--	--	--	0.06	--	--	--	--
Tetrachloroethylene (PCE)	1391.87	11.70	115.83	0.97	--	1.1	0.08	--	1.2	1.8	--
Toluene	2112.67	--	77.87	--	--	3.9	0.04	--	18	28	--
Trichloroethylene (TCE)	125.92	0.90	6.81	0.05	46.7	3	0.05	2.5	27	29	--
Vinyl chloride	87.83	2.99	19.47	0.66	17.2	--	0.22	3.8	--	--	--
cis-1,2-Dichloroethylene	309.61	--	6.81	--	82.8	--	0.02	1.8	0.13	--	0.13
p-Isopropyltoluene	318.95	--	77.87	--	--	--	0.24	--	--	--	--
sec-Butylbenzene	98.54	--	6.81	--	--	--	0.07	--	--	--	--
trans-1,2-Dichloroethylene	277.91	--	13.63	--	--	--	0.05	--	--	--	--

Notes:
Only detected values are presented.
-- = An IPIMAL was not calculated because there was no toxicity value available. Or, the COPC was not detected.
IPIMAL = Inhalation Pathway Interim Measure Action Level
The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:
Cancer Risk (CR) = 1E-06
Hazard Quotient (HQ) = 0.1
Noncancer = Noncancer-Based IPIMAL
Cancer = Cancer-Based IPIMAL
IA = Indoor Air
AA = Ambient Air
[1]Modeled Indoor Air Concentration = (Maximum Detected Groundwater Concentration) x (Groundwater-to-Indoor Air Volatilzation Factor [GIVF])

Table B-3 – Tier 3 Re-Evaluation for 508 South Mead (Design Center)
Building Type: Commercial

COPC	COPC Detected in Groundwater and Indoor Air: With Corrected Indoor Air Concentration (IA-AA): Commercial Noncancer Exceedance Factor NCEF	With Corrected Indoor Air Concentration (IA-AA): Commercial Cancer Exceedance Factor CEF	With Uncorrected Indoor Air Concentration: Commercial Noncancer Exceedance Factor NCEF	With Uncorrected Indoor Air Concentration: Commercial Cancer Exceedance Factor CEF
1,1,1-Trichloroethane	--	--	--	--
1,1-Dichloroethane	--	--	--	--
1,1-Dichloroethylene	0.01	--	0.01	--
1,2,4-Trimethylbenzene	--	--	--	--
1,2-Dichloroethane	--	--	0.5	2.0
1,3,5-Trimethylbenzene	--	--	--	--
2-Hexanone	--	--	--	--
Benzene	--	--	0.4	3.2
Chloroethane	--	--	--	--
Chloroform	--	--	--	--
Ethylbenzene	--	--	--	--
Naphthalene	--	--	--	--
Propylbenzene	--	--	--	--
Tetrachloroethylene	--	--	--	--
Toluene	--	--	--	--
Trichloroethylene	--	--	4.0	540.0
Vinyl chloride	--	--	--	--
cis-1,2-Dichloroethylene	0.02	--	0.02	--
p-Isopropyltoluene	--	--	--	--
sec-Butylbenzene	--	--	--	--
trans-1,2-Dichloroethylene	--	--	--	--
Total:	**0.02**	--	**4.9**	**545.2**

Notes:

-- = Not calculated. NCEFs and CEFs were only calculated for COPCs that exhibited a complete exposure pathway for the groundwater to indoor air vapor intrusion pathway (i.e. the COPC was detected in groundwater and indoor air).

IPIMAL = Inhalation Pathway Interim Measure Action Level

The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:

Cancer Risk (CR) = 1E-06

Hazard Quotient (HQ) = 0.1

Noncancer = Noncancer-Based IPIMAL

Cancer = Cancer-Based IPIMAL

IA = Indoor Air

AA = Ambient Air

NCEF = Noncancer exceedance factor = Indoor Air Concentration / Noncancer IPIMAL

CEF = Cancer exceedance factor = Indoor Air Concentration / Cancer IPIMAL

Table B-4 – Tier 3 Re-Evaluation for 500 South Lucile
Building Type: Commercial

COPC	Commercial Groundwater IPIMAL		Commercial Air IPIMAL		Maximum Detected Groundwater Concentration	Maximum Detected Soil-Gas Concentration	Groundwater to Indoor Air VF	Modeled Indoor Air Concentration Based on Groundwater Using GIVFs[1]	Maximum Detected Indoor Air Concentration	Maximum Detected Ambient Air Concentration	Corrected Indoor Air Concentration (IA - AA)
	Noncancer	Cancer	Noncancer	Cancer							
	ug/L	ug/L	ug/m^3	ug/m^3	ug/L	ug/m^3	ug/m^3 / ug/L	ug/m^3	ug/m^3	ug/m^3	ug/m^3
1,1,1-Trichloroethane	4662.64094	--	429.24	--	--	1	0.09	--	0.64	0.56	0.08
1,1-Dichloroethane	3200.43741	--	97.33333	--	6.13	--	0.03	0.19	--	--	--
1,1-Dichloroethylene	226.57037	--	38.93333	--	--	--	0.17	--	--	--	--
1,2,4-Trimethylbenzene	55.41896	--	1.15827	--	--	2.6	0.02	--	3.7	2.9	0.8
1,2-Dichloroethane	127.79713	30.09352	0.95387	0.22462	--	--	0.01	--	--	--	--
1,3,5-Trimethylbenzene	41.56993	--	1.15827	--	--	0.96	0.03	--	1.4	1	0.4
2-Hexanone	2593.2581	--	3.40667	--	--	--	0.001	--	1.5	--	1.5
Benzene	174.86416	22.41848	5.84	0.74872	--	1.9	0.03	--	10	1.6	8.4
Chloroethane	23154.44252	--	1946.66667	--	--	--	0.08	--	--	--	--
Chloroform	22.14312	9.59546	0.58595	0.25391	--	0.13	0.03	--	0.71	--	0.71
Ethylbenzene	5375.73904	--	194.66667	--	--	1.6	0.04	--	2.4	1.8	0.6
Naphthalene	251.91339	--	0.584	--	--	--	0.002	--	--	--	--
Propylbenzene	114.40011	--	6.81333	--	--	--	0.06	--	--	--	--
Tetrachloroethylene (PCE)	1391.87329	11.69641	115.82667	0.97333	--	12	0.08	--	0.88	0.54	0.34
Toluene	2112.66762	--	77.86667	--	--	9.8	0.04	--	32	15	17
Trichloroethylene (TCE)	125.92425	0.9	6.81333	0.05	0.133	3.4	0.05	0.01	1	0.68	0.32
Vinyl chloride	87.82699	2.9941	19.46667	0.66364	0.034	--	0.22	0.01	--	--	--
cis-1,2-Dichloroethylene	309.61302	--	6.81333	--	7.15	--	0.02	0.16	--	--	--
p-Isopropyltoluene	318.95372	--	77.86667	--	--	--	0.24	--	--	--	--
sec-Butylbenzene	98.54291	--	6.81333	--	--	--	0.07	--	--	--	--
trans-1,2-Dichloroethylene	277.90825	--	13.62667	--	--	--	0.05	--	--	--	--

Notes:
Only detected values are presented.
-- = An IPIMAL was not calculated because there was no toxicity value available. Or, the COPC was not detected.
IPIMAL = Inhalation Pathway Interim Measure Action Level
The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:
Cancer Risk (CR) = 1E-06
Hazard Quotient (HQ) = 0.1
Noncancer = Noncancer-Based IPIMAL
Cancer = Cancer-Based IPIMAL
IA = Indoor Air
AA = Ambient Air
[1]Modeled Indoor Air Concentration = (Maximum Detected Groundwater Concentration) x (Groundwater-to-Indoor Air Volatilzation Factor [GIVF])

Table B-4 – Tier 3 Re-Evaluation for 500 South Lucile
Building Type: Commercial

	COPC Detected in Groundwater and Indoor Air			
	With Corrected Indoor Air Concentration (IA-AA)		With Uncorrected Indoor Air Concentration	
	Commercial Noncancer Exceedance Factor	Commercial Cancer Exceedance Factor	Commercial Noncancer Exceedance Factor	Commercial Cancer Exceedance Factor
COPC	NCEF	CEF	NCEF	CEF
1,1,1-Trichloroethane	--	--	--	--
1,1-Dichloroethane	--	--	--	--
1,1-Dichloroethylene	--	--	--	--
1,2,4-Trimethylbenzene	--	--	--	--
1,2-Dichloroethane	--	--	--	--
1,3,5-Trimethylbenzene	--	--	--	--
2-Hexanone	--	--	--	--
Benzene	--	--	--	--
Chloroethane	--	--	--	--
Chloroform	--	--	--	--
Ethylbenzene	--	--	--	--
Naphthalene	--	--	--	--
Propylbenzene	--	--	--	--
Tetrachloroethylene (PCE)	--	--	--	--
Toluene	--	--	--	--
Trichloroethylene (TCE)	0.05	6.4	0.15	20.0
Vinyl chloride	--	--	--	--
cis-1,2-Dichloroethylene	--	--	--	--
p-Isopropyltoluene	--	--	--	--
sec-Butylbenzene	--	--	--	--
trans-1,2-Dichloroethylene	--	--	--	--
Total	**0.05**	**6.4**	**0.15**	**20.0**

Notes:

-- = Not calculated. NCEFs and CEFs were only calculated for COPCs that exhibited a complete exposure pathway for the groundwater to indoor air vapor intrusion pathway (i.e. the COPC was detected in groundwater and indoor air).

IPIMAL = Inhalation Pathway Interim Measure Action Level

The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:

Cancer Risk (CR) = 1E-06

Hazard Quotient (HQ) = 0.1

Noncancer = Noncancer-Based IPIMAL

Cancer = Cancer-Based IPIMAL

IA = Indoor Air

AA = Ambient Air

NCEF = Noncancer exceedance factor = Indoor Air Concentration / Noncancer IPIMAL

CEF = Cancer exceedance factor = Indoor Air Concentration / Cancer IPIMAL

Table B-5 – Tier 3 Re-Evaluation for 5600 6th Avenue South
Building Type: Commercial

COPC	Commercial Groundwater IPIMAL		Commercial Air IPIMAL		Maximum Detected Groundwater Concentration	Maximum Detected Soil-Gas Concentration	Groundwater to Indoor Air VF	Modeled Indoor Air Concentration Based on Groundwater Using GIVFs[1]	Maximum Detected Indoor Air Concentration	Maximum Detected Ambient Air Concentration	Corrected Indoor Air Concentration (IA - AA)
	Noncancer	Cancer	Noncancer	Cancer							
	ug/L	ug/L	ug/m^3	ug/m^3	ug/L	ug/m^3	ug/m^3 / ug/L	ug/m^3	ug/m^3	ug/m^3	ug/m^3
1,1,1,2-Tetrachloroethane	--	--	--	--	--	--	--	--	--	--	--
1,1,1-Trichloroethane	4662.6	--	429.2	--	--	5.3	0.09	--	0.99	--	0.99
1,1,2-Trichloroethane	--	67.8	--	0.4	--	--	--	--	--	--	--
1,1,2-Trichlorotrifluoroethane	5147.3	--	5840.0	--	--	--	--	--	--	--	--
1,1-Dichloroethane	3200.4	--	97.3	--	2.11	--	0.03	0.06	--	--	--
1,1-Dichloroethylene	226.6	--	38.9	--	0.32	--	0.17	0.05	--	--	--
1,2,4-Trimethylbenzene	55.4	--	1.2	--	--	0.3	0.02	--	2.6	1.9	0.7
1,2-Dichlorobenzene	4764.2	--	38.9	--	--	--	--	--	--	--	--
1,2-Dichloroethane	127.8	30.1	1.0	0.2	--	--	--	--	--	--	--
1,2-Dichloropropane	--	--	--	--	--	--	--	--	--	--	--
1,3,5-Trimethylbenzene	41.6	--	1.2	--	--	--	--	--	0.95	0.75	0.2
1,3-Butadiene	--	--	--	--	--	--	--	--	--	--	--
1,3-Dichlorobenzene	--	--	--	--	--	--	--	--	--	--	--
1,4-Dichlorobenzene	--	--	--	--	--	--	--	--	--	--	--
2-Chloroethylvinyl ether	--	--	--	--	--	--	--	--	--	--	--
2-Hexanone	2593.3	--	3.4	--	--	--	--	--	--	--	--
4-Ethyltoluene	--	--	--	--	--	--	--	--	--	--	--
Acetone	--	--	--	--	--	--	--	--	--	--	--
Benzene	174.9	22.4	5.8	0.7	--	--	--	--	5.8	5.5	0.3
Bromodichloromethane	--	--	--	--	--	--	--	--	--	--	--
Bromoform	--	--	--	--	--	--	--	--	--	--	--
Bromomethane	--	--	--	--	--	--	--	--	--	--	--
Carbon disulfide	--	--	--	--	--	--	--	--	--	--	--
Carbon tetrachloride	--	--	--	--	--	--	--	--	--	--	--
Chlorobenzene	--	--	--	--	--	--	--	--	--	--	--
Chloroethane	23154.4	--	1946.7	--	--	--	--	--	--	--	--
Chloroform	22.1	9.6	0.6	0.3	--	--	--	--	1.9	--	1.9
Chloromethane	--	--	--	--	--	--	--	--	--	--	--
Cumene	319.0	--	77.9	--	--	--	--	--	--	--	--
Dibromochloromethane	--	--	--	--	--	--	--	--	--	--	--
Ethylbenzene	5375.7	--	194.7	--	--	--	--	--	3.2	2.3	0.9
Methyl ethyl ketone	--	--	--	--	--	--	--	--	--	--	--
Methyl isobutyl ketone (MIBK)	444558.5	--	584.0	--	--	--	--	--	--	--	--
Methylene chloride	35279.4	750.6	584.0	12.4	--	--	--	--	--	--	--
Naphthalene	251.9	--	0.6	--	--	--	--	--	--	--	--
Propylbenzene	114.4	--	6.8	--	--	--	--	--	--	--	--
Styrene	--	--	--	--	--	--	--	--	--	--	--
Tetrachloroethylene (PCE)	1391.9	11.7	115.8	1.0	0.38	4.8	0.08	0.03	1	0.87	0.13
Toluene	2112.7		77.9			0.54	0.04		29	17	12
Trichloroethylene (TCE)	125.9	0.9	6.8	0.05	11.5		0.05	0.62	0.655	0.41	0.245

Table B-5 – Tier 3 Re-Evaluation for 5600 6th Avenue South
Building Type: Commercial

COPC	Commercial Groundwater IPIMAL		Commercial Air IPIMAL		Maximum Detected Groundwater Concentration	Maximum Detected Soil-Gas Concentration	Groundwater to Indoor Air VF	Modeled Indoor Air Concentration Based on Groundwater Using GIVFs[1]	Maximum Detected Indoor Air Concentration	Maximum Detected Ambient Air Concentration	Corrected Indoor Air Concentration (IA - AA)
	Noncancer	Cancer	Noncancer	Cancer							
	ug/L	ug/L	ug/m^3	ug/m^3	ug/L	ug/m^3	ug/m^3 / ug/L	ug/m^3	ug/m^3	ug/m^3	ug/m^3
Trichlorofluoromethane	--	--	--	--	--	--	--	--	--	--	--
Vinyl acetate	--	--	--	--	--	--	--	--	--	--	--
Vinyl chloride	87.8	3.0	19.5	0.7	--	--	--	--	--	0.24	--
cis-1,2-Dichloroethylene	309.6	--	6.8	--	1.96	--	0.02	0.04	--	--	--
cis-1,3-Dichloropropene	--	--	--	--	--	--	--	--	--	--	--
m,p-Xylenes	--	--	--	--	--	--	--	--	--	--	--
n-Butylbenzene	--	--	--	--	--	--	--	--	--	--	--
o-Xylene	--	--	--	--	--	--	--	--	--	--	--
p-Isopropyltoluene	319.0	--	77.9	--	--	--	--	--	--	--	--
sec-Butylbenzene	98.5	--	6.8	--	--	--	--	--	--	--	--
trans-1,2-Dichloroethylene	277.9	--	13.6	--	--	--	--	--	--	--	--
trans-1,3-Dichloropropene	--	--	--	--	--	--	--	--	--	--	--

Notes:
Only detected values are presented.
-- = An IPIMAL was not calculated because there was no toxicity value available. Or, the COPC was not detected.
IPIMAL = Inhalation Pathway Interim Measure Action Level
The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:
  Cancer Risk (CR) = 1E-06
  Hazard Quotient (HQ) = 0.1
Noncancer = Noncancer-Based IPIMAL
Cancer = Cancer-Based IPIMAL
IA = Indoor Air
AA = Ambient Air
[1]Modeled Indoor Air Concentration = (Maximum Detected Groundwater Concentration) x (Groundwater-to-Indoor Air Volatilzation Factor [GIVF])

Table B-5 – Tier 3 Re-Evaluation for 5600 6th Avenue South
Building Type: Commercial

COPC	COPC Detected in Groundwater and Indoor Air: With Corrected Indoor Air Concentration (IA-AA): Commercial Noncancer Exceedance Factor NCEF	With Corrected Indoor Air Concentration (IA-AA): Commercial Cancer Exceedance Factor CEF	With Uncorrected Indoor Air Concentration: Commercial Noncancer Exceedance Factor NCEF	With Uncorrected Indoor Air Concentration: Commercial Cancer Exceedance Factor CEF
1,1,1,2-Tetrachloroethane	--	--	--	--
1,1,1-Trichloroethane	--	--	--	--
1,1,2-Trichloroethane	--	--	--	--
1,1,2-Trichlorotrifluoroethane	--	--	--	--
1,1-Dichloroethane	--	--	--	--
1,1-Dichloroethylene	--	--	--	--
1,2,4-Trimethylbenzene	--	--	--	--
1,2-Dichlorobenzene	--	--	--	--
1,2-Dichloroethane	--	--	--	--
1,2-Dichloropropane	--	--	--	--
1,3,5-Trimethylbenzene	--	--	--	--
1,3-Butadiene	--	--	--	--
1,3-Dichlorobenzene	--	--	--	--
1,4-Dichlorobenzene	--	--	--	--
2-Chloroethylvinyl ether	--	--	--	--
2-Hexanone	--	--	--	--
4-Ethyltoluene	--	--	--	--
Acetone	--	--	--	--
Benzene	--	--	--	--
Bromodichloromethane	--	--	--	--
Bromoform	--	--	--	--
Bromomethane	--	--	--	--
Carbon disulfide	--	--	--	--
Carbon tetrachloride	--	--	--	--
Chlorobenzene	--	--	--	--
Chloroethane	--	--	--	--
Chloroform	--	--	--	--
Chloromethane	--	--	--	--
Cumene	--	--	--	--
Dibromochloromethane	--	--	--	--
Ethylbenzene	--	--	--	--
Methyl ethyl ketone	--	--	--	--
Methyl isobutyl ketone (MIBK)	--	--	--	--
Methylene chloride	--	--	--	--
Naphthalene	--	--	--	--
Propylbenzene	--	--	--	--
Styrene	--	--	--	--
Tetrachloroethylene (PCE)	0.001	0.1	0.01	1.0
Toluene	--	--	--	--
Trichloroethylene (TCE)	0.04	4.8	0.1	12.8

Table B-5 – Tier 3 Re-Evaluation for 5600 6th Avenue South
Building Type: Commercial

	COPC Detected in Groundwater and Indoor Air			
	With Corrected Indoor Air Concentration (IA-AA)		With Uncorrected Indoor Air Concentration	
	Commercial Noncancer Exceedance Factor	Commercial Cancer Exceedance Factor	Commercial Noncancer Exceedance Factor	Commercial Cancer Exceedance Factor
COPC	NCEF	CEF	NCEF	CEF
Trichlorofluoromethane	--	--	--	--
Vinyl acetate	--	--	--	--
Vinyl chloride	--	--	--	--
cis-1,2-Dichloroethylene	--	--	--	--
cis-1,3-Dichloropropene	--	--	--	--
m,p-Xylenes	--	--	--	--
n-Butylbenzene	--	--	--	--
o-Xylene	--	--	--	--
p-Isopropyltoluene	--	--	--	--
sec-Butylbenzene	--	--	--	--
trans-1,2-Dichloroethylene	--	--	--	--
trans-1,3-Dichloropropene	--	--	--	--
Total	**0.04**	**4.9**	**0.1**	**13.8**

Notes:

-- = Not calculated. NCEFs and CEFs were only calculated for COPCs that exhibited a complete exposure pathway for the groundwater to indoor air vapor intrusion pathway (i.e. the COPC was detected in groundwater and indoor air).

IPIMAL = Inhalation Pathway Interim Measure Action Level

The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:

Cancer Risk (CR) = 1E-06

Hazard Quotient (HQ) = 0.1

Noncancer = Noncancer-Based IPIMAL

Cancer = Cancer-Based IPIMAL

IA = Indoor Air

AA = Ambient Air

NCEF = Noncancer exceedance factor = Indoor Air Concentration / Noncancer IPIMAL

CEF = Cancer exceedance factor = Indoor Air Concentration / Cancer IPIMAL

Table B-6 – Tier 3 Re-Evaluation for 5606 2nd Avenue South
Building Type: Residential

COPC	Residential Groundwater IPIMAL Noncancer ug/L	Residential Groundwater IPIMAL Cancer ug/L	Residential Air IPIMAL Noncancer ug/m^3	Residential Air IPIMAL Cancer ug/m^3	Maximum Detected Groundwater Concentration ug/L	Maximum Detected Soil-Gas Concentration ug/m^3	Groundwater to Indoor Air VF ug/m^3 / ug/L	Modeled Indoor Air Concentration Based on Groundwater Using GIVFs[1] ug/m^3	Maximum Detected Indoor Air Concentration ug/m^3	Maximum Detected Ambient Air Concentration ug/m^3	Corrected Indoor Air Concentration (IA - AA) ug/m^3
1,1,1-Trichloroethane	1094.95	--	100.80	--	--	1	0.09	--	3.5	--	3.5
1,1-Dichloroethane	751.57	--	22.86	--	--	--	0.03	--	--	--	--
1,1-Dichloroethylene	53.21	--	9.14	--	0.0051	--	0.17	0.001	--	--	--
1,2,4-Trimethylbenzene	13.01	--	0.27	--	--	0.67	0.02	--	0.57	0.98	--
1,2-Dichloroethane	30.01	10.41	0.22	0.08	--	--	0.01	--	0.07	0.088	--
1,3,5-Trimethylbenzene	9.76	--	0.27	--	--	0.36	0.03	--	0.18	0.33	--
2-Hexanone	608.98	--	0.80	--	--	--	0.00	--	2	1.2	0.8
Benzene	41.06	7.76	1.37	0.26	9.63	0.34	0.03	0.32	0.98	3.4	--
Chloroethane	5437.44	--	457.14	--	--	--	0.08	--	--	--	--
Chloroform	84.65	3.32	2.24	0.09	--	--	0.03	--	0.75	0.12	0.63
Ethylbenzene	1262.40	--	45.71	--	--	16	0.04	--	0.75	1.6	--
Naphthalene	59.16	--	0.14	--	11.6	13	0.00	0.03	--	--	--
Propylbenzene	26.87	--	1.60	--	--	--	0.06	--	--	--	--
Tetrachloroethylene (PCE)	326.86	4.05	27.20	0.34	--	1.3	0.08	--	--	0.97	--
Toluene	496.13	--	18.29	--	9.5	0.85	0.04	0.35	4.8	10	--
Trichloroethylene (TCE)	29.57	0.40	1.60	0.02	0.24	--	0.05	0.01	0.15	0.2	--
Vinyl chloride	20.62	1.04	4.57	0.23	--	--	0.22	--	--	0.096	--
cis-1,2-Dichloroethylene	72.71	--	1.60	--	0.56	--	0.02	0.01	--	--	--
p-Isopropyltoluene	74.90	--	18.29	--	--	--	0.24	--	--	--	--
sec-Butylbenzene	23.14	--	1.60	--	--	--	0.07	--	--	--	--
trans-1,2-Dichloroethylene	65.26	--	3.20	--	--	--	0.05	--	--	--	--

Notes:
Only detected values are presented.
-- = An IPIMAL was not calculated because there was no toxicity value available. Or, the COPC was not detected.
IPIMAL = Inhalation Pathway Interim Measure Action Level
The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:
Cancer Risk (CR) = 1E-06
Hazard Quotient (HQ) = 0.1
Noncancer = Noncancer-Based IPIMAL
Cancer = Cancer-Based IPIMAL
IA = Indoor Air
AA = Ambient Air
[1]Modeled Indoor Air Concentration = (Maximum Detected Groundwater Concentration) x (Groundwater-to-Indoor Air Volatilzation Factor [GIVF])

Table B-6 – Tier 3 Re-Evaluation for 5606 2nd Avenue South
Building Type: Residential

COPC	COPC Detected in Groundwater and Indoor Air			
	With Corrected Indoor Air Concentration (IA-AA)		With Uncorrected Indoor Air Concentration	
	Residential Noncancer Exceedance Factor NCEF	Residential Cancer Exceedance Factor CEF	Residential Noncancer Exceedance Factor NCEF	Residential Cancer Exceedance Factor CEF
1,1,1-Trichloroethane	--	--	--	--
1,1-Dichloroethane	--	--	--	--
1,1-Dichloroethylene	--	--	--	--
1,2,4-Trimethylbenzene	--	--	--	--
1,2-Dichloroethane	--	--	--	--
1,3,5-Trimethylbenzene	--	--	--	--
2-Hexanone	--	--	--	--
Benzene	--	--	0.7	3.8
Chloroethane	--	--	--	--
Chloroform	--	--	--	--
Ethylbenzene	--	--	--	--
Naphthalene	--	--	--	--
Propylbenzene	--	--	--	--
Tetrachloroethylene (PCE)	--	--	--	--
Toluene	--	--	0.3	--
Trichloroethylene (TCE)	--	--	0.1	7.5
Vinyl chloride	--	--	--	--
cis-1,2-Dichloroethylene	--	--	--	--
p-Isopropyltoluene	--	--	--	--
sec-Butylbenzene	--	--	--	--
trans-1,2-Dichloroethylene	--	--	--	--
Total	**--**	**--**	**1.1**	**11.3**

Notes:

-- = Not calculated. NCEFs and CEFs were only calculated for COPCs that exhibited a complete exposure pathway for the groundwater to indoor air vapor intrusion pathway (i.e. the COPC was detected in groundwater and indoor air).

IPIMAL = Inhalation Pathway Interim Measure Action Level

The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:

Cancer Risk (CR) = 1E-06

Hazard Quotient (HQ) = 0.1

Noncancer = Noncancer-Based IPIMAL

Cancer = Cancer-Based IPIMAL

IA = Indoor Air

AA = Ambient Air

NCEF = Noncancer exceedance factor = Indoor Air Concentration / Noncancer IPIMAL

CEF = Cancer exceedance factor = Indoor Air Concentration / Cancer IPIMAL

Table B-7 – Tier 3 Re-Evaluation for 5610 2nd Avenue South
Building Type: Residential

COPC	Residential Groundwater IPIMAL Noncancer ug/L	Residential Groundwater IPIMAL Cancer ug/L	Residential Air IPIMAL Noncancer ug/m3	Residential Air IPIMAL Cancer ug/m3	Maximum Detected Groundwater Concentration ug/L	Maximum Detected Soil-Gas Concentration ug/m3	Groundwater to Indoor Air VF (ug/m3 / ug/L) ug/m3 / ug/L	Modeled Indoor Air Concentration Based on Groundwater Using GIVFs[1] ug/m3	Maximum Detected Indoor Air Concentration ug/m3	Maximum Detected Ambient Air Concentration ug/m3	Corrected Indoor Air Concentration (IA - AA) ug/m3
1,1,1-Trichloroethane	1094.95	--	100.80	--	--	--	0.09	--	--	--	--
1,1-Dichloroethane	751.57	--	22.86	--	--	--	0.03	--	--	--	--
1,1-Dichloroethylene	53.21	--	9.14	--	0.0051	--	0.17	0.001	--	--	--
1,2,4-Trimethylbenzene	13.01	--	0.27	--	--	0.52	0.02	--	0.61	0.98	--
1,2-Dichloroethane	30.01	10.41	0.22	0.08	--	--	0.01	--	--	0.088	--
1,3,5-Trimethylbenzene	9.76	--	0.27	--	--	0.28	0.03	--	0.2	0.33	--
2-Hexanone	608.98	--	0.80	--	--	--	0.00	--	1.2	1.2	--
Benzene	41.06	7.76	1.37	0.26	9.63	0.61	0.03	0.32	0.92	3.4	--
Chloroethane	5437.44	--	457.14	--	--	--	0.08	--	--	--	--
Chloroform	84.65	3.32	2.24	0.09	--	0.32	0.03	--	0.82	0.12	0.7
Ethylbenzene	1262.40	--	45.71	--	--	140	0.04	--	1	1.6	--
Naphthalene	59.16	--	0.14	--	11.6	6.2	0.00	0.03	--	--	--
Propylbenzene	26.87	--	1.60	--	--	--	0.06	--	--	--	--
Tetrachloroethylene (PCE)	326.86	4.05	27.20	0.34	--	--	0.08	--	0.93	0.97	--
Toluene	496.13	--	18.29	--	9.5	2.2	0.04	0.35	12	10	2
Trichloroethylene (TCE)	29.57	0.40	1.60	0.02	0.24	--	0.05	0.01	0.14	0.2	--
Vinyl chloride	20.62	1.04	4.57	0.23	--	--	0.22	--	--	0.096	--
cis-1,2-Dichloroethylene	72.71	--	1.60	--	0.56	--	0.02	0.01	--	--	--
p-Isopropyltoluene	74.90	--	18.29	--	--	--	0.24	--	--	--	--
sec-Butylbenzene	23.14	--	1.60	--	--	--	0.07	--	--	--	--
trans-1,2-Dichloroethylene	65.26	--	3.20	--	--	--	0.05	--	--	--	--

Notes:
Only detected values are presented.
-- = An IPIMAL was not calculated because there was no toxicity value available. Or, the COPC was not detected.
IPIMAL = Inhalation Pathway Interim Measure Action Level
The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:
Cancer Risk (CR) = 1E-06
Hazard Quotient (HQ) = 0.1
Noncancer = Noncancer-Based IPIMAL
Cancer = Cancer-Based IPIMAL
IA = Indoor Air
AA = Ambient Air
[1]Modeled Indoor Air Concentration = (Maximum Detected Groundwater Concentration) x (Groundwater-to-Indoor Air Volatilzation Factor [GIVF])

Table B-7 – Tier 3 Re-Evaluation for 5610 2nd Avenue South
Building Type: Residential

	COPC Detected in Groundwater and Indoor Air			
	With Corrected Indoor Air Concentration (IA-AA)		With Uncorrected Indoor Air Concentration	
	Residential Noncancer Exceedance Factor	Residential Cancer Exceedance Factor	Residential Noncancer Exceedance Factor	Residential Cancer Exceedance Factor
COPC	**NCEF**	**CEF**	**NCEF**	**CEF**
1,1,1-Trichloroethane	--	--	--	--
1,1-Dichloroethane	--	--	--	--
1,1-Dichloroethylene	--	--	--	--
1,2,4-Trimethylbenzene	--	--	--	--
1,2-Dichloroethane	--	--	--	--
1,3,5-Trimethylbenzene	--	--	--	--
2-Hexanone	--	--	--	--
Benzene	--	--	0.7	3.6
Chloroethane	--	--	--	--
Chloroform	--	--	--	--
Ethylbenzene	--	--	--	--
Naphthalene	--	--	--	--
Propylbenzene	--	--	--	--
Tetrachloroethylene (PCE)	--	--	--	--
Toluene	0.1	--	0.7	--
Trichloroethylene (TCE)	--	--	0.1	7.0
Vinyl chloride	--	--	--	--
cis-1,2-Dichloroethylene	--	--	--	--
p-Isopropyltoluene	--	--	--	--
sec-Butylbenzene	--	--	--	--
trans-1,2-Dichloroethylene	--	--	--	--
Total	**0.1**	**--**	**1.4**	**10.6**

Notes:

-- = Not calculated. NCEFs and CEFs were only calculated for COPCs that exhibited a complete exposure pathway for the groundwater to indoor air vapor intrusion pathway (i.e. the COPC was detected in groundwater and indoor air).

IPIMAL = Inhalation Pathway Interim Measure Action Level

The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:

Cancer Risk (CR) = 1E-06

Hazard Quotient (HQ) = 0.1

Noncancer = Noncancer-Based IPIMAL

Cancer = Cancer-Based IPIMAL

IA = Indoor Air

AA = Ambient Air

NCEF = Noncancer exceedance factor = Indoor Air Concentration / Noncancer IPIMAL

CEF = Cancer exceedance factor = Indoor Air Concentration / Cancer IPIMAL

Table B-8 – Tier 3 Re-Evaluation for 5706 2nd Avenue South
Building Type: Commercial

COPC	Commercial Groundwater IPIMAL		Commercial Air IPIMAL		Maximum Detected Groundwater Concentration	Maximum Detected Soil-Gas Concentration	Groundwater to Indoor Air VF	Modeled Indoor Air Concentration Based on Groundwater Using GIVFs[1]	Maximum Detected Indoor Air Concentration	Maximum Detected Ambient Air Concentration	Corrected Indoor Air Concentration (IA - AA)
	Noncancer	Cancer	Noncancer	Cancer							
	ug/L	ug/L	ug/m^3	ug/m^3	ug/L	ug/m^3	ug/m^3 / ug/L	ug/m^3	ug/m^3	ug/m^3	ug/m^3
1,1,1,2-Tetrachloroethane	--	--	--	--	--	--		--	--	--	--
1,1,1-Trichloroethane	4662.6	--	429.2	--	--	1.5	0.09	--	14	0.23	13.77
1,1,2-Trichloroethane	--	67.8	--	0.4	--	--	0.01	--	--	--	--
1,1,2-Trichlorotrifluoroethane	5147.3	--	5840.0	--	--	--	1.13	--	--	--	--
1,1-Dichloroethane	3200.4	--	97.3	--	--	--	0.03	--	--	--	--
1,1-Dichloroethylene	226.6	--	38.9	--	--	--	0.17	--	--	--	--
1,2,4-Trimethylbenzene	55.4	--	1.2	--	--	0.57	0.02	--	0.97	1.1	--
1,2-Dichlorobenzene	4764.2	--	38.9	--	--	--	0.01	--	--	--	--
1,2-Dichloroethane	127.8	30.1	1.0	0.2	--	--	0.01	--	--	--	--
1,2-Dichloropropane	--	--	--	--	--	--	--	--	--	--	--
1,3,5-Trimethylbenzene	41.6		1.2			0.21	0.03	--	0.35	0.43	--
1,3-Butadiene	--	--	--	--	--	--	--	--	--	--	--
1,3-Dichlorobenzene	--	--	--	--	--	--		--	--	--	--
1,4-Dichlorobenzene	--	--	--	--	--	--	0.01	--	--	--	--
2-Chloroethylvinyl ether	--	--	--	--	--	--	0.00	--	--	--	--
2-Hexanone	2593.3	--	3.4	--	--	--	0.00	--	--	--	--
4-Ethyltoluene	--	--	--	--	--	--		--	--	--	--
Acetone	--	--	--	--	--	--	0.00	--	--	--	--
Benzene	174.9	22.4	5.8	0.7	--	0.42	0.03	--	2.3	3.7	--
Bromodichloromethane	--	--	--	--	--	--		--	--	--	--
Bromoform	--	--	--	--	--	--		--	--	--	--
Bromomethane	--	--	--	--	--	--		--	--	--	--
Carbon disulfide	--	--	--	--	--	--	0.22	--	--	--	--
Carbon tetrachloride	--	--	--	--	--	--	0.16	--	--	--	--
Chlorobenzene	--	--	--	--	--	--	0.02	--	--	--	--
Chloroethane	23154.4	--	1946.7	--	--	--	0.08	--	--	--	--
Chloroform	22.1	9.6	0.6	0.3	--	--	0.03	--	0.2	--	0.2
Chloromethane	--	--	--	--	--	--		--	--	--	--
Cumene	319.0	--	77.9	--	--	--	0.24	--	--	--	--
Dibromochloromethane	--	--	--	--	--	--		--	--	--	--
Ethylbenzene	5375.7	--	194.7	--	--	0.28	0.04	--	1.3	1.8	--
Methyl ethyl ketone	--	--	--	--	--	--		--	--	--	--
Methyl isobutyl ketone (MIBK)	444558.5	--	584.0	--	--	--	0.00	--	--	--	--
Methylene chloride	35279.4	750.6	584.0	12.4	--	--	0.02	--	--	--	--
Naphthalene	251.9	--	0.6	--	--	--	0.00	--	--	--	--
Propylbenzene	114.4	--	6.8	--	--	--	0.06	--	--	--	--
Styrene	--	--	--	--	--	--	0.01	--	--	--	--
Tetrachloroethylene (PCE)	1391.9	11.7	115.8	1.0	--	6.2	0.08	--	1.3	0.81	0.49
Toluene	2112.7	--	77.9	--	--	1.4	0.04	--	10	14	
Trichloroethylene (TCE)	125.9	0.9	6.8	0.05	0.09	0.34	0.05	0.005	0.8	0.4	0.4

Table B-8 – Tier 3 Re-Evaluation for 5706 2nd Avenue South
Building Type: Commercial

COPC	Commercial Groundwater IPIMAL		Commercial Air IPIMAL		Maximum Detected Groundwater Concentration	Maximum Detected Soil-Gas Concentration	Groundwater to Indoor Air VF	Modeled Indoor Air Concentration Based on Groundwater Using GIVFs[1]	Maximum Detected Indoor Air Concentration	Maximum Detected Ambient Air Concentration	Corrected Indoor Air Concentration (IA - AA)
	Noncancer	Cancer	Noncancer	Cancer							
	ug/L	ug/L	ug/m^3	ug/m^3	ug/L	ug/m^3	ug/m^3 / ug/L	ug/m^3	ug/m^3	ug/m^3	ug/m^3
Trichlorofluoromethane	--	--	--	--	--	--	0.38	--	--	--	--
Vinyl acetate	--	--	--	--	--	--		--	--	--	--
Vinyl chloride	87.8	3.0	19.5	0.7	--	--	0.22	--	--	0.12	--
cis-1,2-Dichloroethylene	309.6	--	6.8	--	--	--	0.02	--	--	--	--
cis-1,3-Dichloropropene	--	--	--	--	--	--	0.08	--	--	--	--
m,p-Xylenes	--	--	--	--	--	--		--	--	--	--
n-Butylbenzene	--	--	--	--	--	--	0.07	--	--	--	--
o-Xylene	--	--	--	--	--	--		--	--	--	--
p-Isopropyltoluene	319.0	--	77.9	--	--	--	0.24	--	--	--	--
sec-Butylbenzene	98.5	--	6.8	--	--	--	0.07	--	--	--	--
trans-1,2-Dichloroethylene	277.9	--	13.6	--	--	--	0.05	--	--	--	--
trans-1,3-Dichloropropene	--	--	--	--	--	--	0.08	--	--	--	--

Notes:
Only detected values are presented.
-- = An IPIMAL was not calculated because there was no toxicity value available. Or, the COPC was not detected.
IPIMAL = Inhalation Pathway Interim Measure Action Level
The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:
Cancer Risk (CR) = 1E-06
Hazard Quotient (HQ) = 0.1
Noncancer = Noncancer-Based IPIMAL
Cancer = Cancer-Based IPIMAL
IA = Indoor Air
AA = Ambient Air
[1]Modeled Indoor Air Concentration = (Maximum Detected Groundwater Concentration) x (Groundwater-to-Indoor Air Volatilzation Factor [GIVF])

Table B-8 – Tier 3 Re-Evaluation for 5706 2nd Avenue South
Building Type: Commercial

	COPC Detected in Groundwater and Indoor Air			
	With Corrected Indoor Air Concentration (IA-AA)		With Uncorrected Indoor Air Concentration	
	Commercial Noncancer Exceedance Factor	Commercial Cancer Exceedance Factor	Commercial Noncancer Exceedance Factor	Commercial Cancer Exceedance Factor
COPC	NCEF	CEF	NCEF	CEF
1,1,1,2-Tetrachloroethane	--	--	--	--
1,1,1-Trichloroethane	--	--	--	--
1,1,2-Trichloroethane	--	--	--	--
1,1,2-Trichlorotrifluoroethane	--	--	--	--
1,1-Dichloroethane	--	--	--	--
1,1-Dichloroethylene	--	--	--	--
1,2,4-Trimethylbenzene	--	--	--	--
1,2-Dichlorobenzene	--	--	--	--
1,2-Dichloroethane	--	--	--	--
1,2-Dichloropropane	--	--	--	--
1,3,5-Trimethylbenzene	--	--	--	--
1,3-Butadiene	--	--	--	--
1,3-Dichlorobenzene	--	--	--	--
1,4-Dichlorobenzene	--	--	--	--
2-Chloroethylvinyl ether	--	--	--	--
2-Hexanone	--	--	--	--
4-Ethyltoluene	--	--	--	--
Acetone	--	--	--	--
Benzene	--	--	--	--
Bromodichloromethane	--	--	--	--
Bromoform	--	--	--	--
Bromomethane	--	--	--	--
Carbon disulfide	--	--	--	--
Carbon tetrachloride	--	--	--	--
Chlorobenzene	--	--	--	--
Chloroethane	--	--	--	--
Chloroform	--	--	--	--
Chloromethane	--	--	--	--
Cumene	--	--	--	--
Dibromochloromethane	--	--	--	--
Ethylbenzene	--	--	--	--
Methyl ethyl ketone	--	--	--	--
Methyl isobutyl ketone (MIBK)	--	--	--	--
Methylene chloride	--	--	--	--
Naphthalene	--	--	--	--
Propylbenzene	--	--	--	--
Styrene	--	--	--	--
Tetrachloroethylene (PCE)	--	--	--	--
Toluene	--	--	--	--
Trichloroethylene (TCE)	0.1	7.8	0.1	15.7

Table B-8 – Tier 3 Re-Evaluation for 5706 2nd Avenue South
Building Type: Commercial

COPC	COPC Detected in Groundwater and Indoor Air: With Corrected Indoor Air Concentration (IA-AA): Commercial Noncancer Exceedance Factor NCEF	With Corrected Indoor Air Concentration (IA-AA): Commercial Cancer Exceedance Factor CEF	With Uncorrected Indoor Air Concentration: Commercial Noncancer Exceedance Factor NCEF	With Uncorrected Indoor Air Concentration: Commercial Cancer Exceedance Factor CEF
Trichlorofluoromethane	--	--	--	--
Vinyl acetate	--	--	--	--
Vinyl chloride	--	--	--	--
cis-1,2-Dichloroethylene	--	--	--	--
cis-1,3-Dichloropropene	--	--	--	--
m,p-Xylenes	--	--	--	--
n-Butylbenzene	--	--	--	--
o-Xylene	--	--	--	--
p-Isopropyltoluene	--	--	--	--
sec-Butylbenzene	--	--	--	--
trans-1,2-Dichloroethylene	--	--	--	--
trans-1,3-Dichloropropene	--	--	--	--
Total	**0.1**	**7.8**	**0.1**	**15.7**

Notes:

-- = Not calculated. NCEFs and CEFs were only calculated for COPCs that exhibited a complete exposure pathway for the groundwater to indoor air vapor intrusion pathway (i.e. the COPC was detected in groundwater and indoor air).

IPIMAL = Inhalation Pathway Interim Measure Action Level

The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:

Cancer Risk (CR) = 1E-06

Hazard Quotient (HQ) = 0.1

Noncancer = Noncancer-Based IPIMAL

Cancer = Cancer-Based IPIMAL

IA = Indoor Air

AA = Ambient Air

NCEF = Noncancer exceedance factor = Indoor Air Concentration / Noncancer IPIMAL

CEF = Cancer exceedance factor = Indoor Air Concentration / Cancer IPIMAL

Table B-9 – Tier 3 Re-Evaluation for 665 South Lucile Street (11/2003 Sample Results)
Building Type: Commercial

	Commercial Groundwater IPIMAL		Commercial Air IPIMAL		Maximum Detected Groundwater Concentration	Maximum Detected Soil-Gas Concentration	Groundwater to Indoor Air VF	Modeled Indoor Air Concentration Based on Groundwater Using GIVFs[1]	Maximum Detected Indoor Air Concentration	Maximum Detected Ambient Air Concentration	Corrected Indoor Air Concentration (IA - AA)
	Noncancer	Cancer	Noncancer	Cancer							
COPC	ug/L	ug/L	ug/m^3	ug/m^3	ug/L	ug/m^3	ug/m^3 / ug/L	ug/m^3	ug/m^3	ug/m^3	ug/m^3
1,1,1-Trichloroethane	4662.64	--	429.24	--	69	350	0.09	6.4	0.31	0.21	0.1
1,1-Dichloroethane	3200.44	--	97.33	--	96.2	--	0.03	2.9	--	--	--
1,1-Dichloroethylene	226.57	--	38.93	--	1.66	0.27	0.17	0.3	--	--	--
1,2,4-Trimethylbenzene	55.42	--	1.16	--	--	1.8	0.02	--	7.6	2.2	5.4
1,2-Dichloroethane	127.80	30.09	0.95	0.22	--	--	0.01	--	2.1	--	2.1
1,3,5-Trimethylbenzene	41.57	--	1.16	--	--	0.755	0.03	--	1.1	0.81	0.29
2-Hexanone	2593.26	--	3.41	--	--	--	0.001	--	--	--	--
Benzene	174.86	22.42	5.84	0.75	--	2.7	0.03	--	12	6.7	5.3
Chloroethane	23154.44	--	1946.67	--	--	--	0.08	--	--	--	--
Chloroform	22.14	9.60	0.59	0.25	--	--	0.03	--	2.1	0.4	1.7
Ethylbenzene	5375.74	--	194.67	--	--	130	0.04	--	26	2.4	23.6
Naphthalene	251.91	--	0.58	--	--	--	0.002	--	--	--	--
Propylbenzene	114.40	--	6.81	--	--	--	0.06	--	--	--	--
Tetrachloroethylene (PCE)	1391.87	11.70	115.83	0.97	1.8	17	0.08	0.1	0.54	1	--
Toluene	2112.67	--	77.87	--	--	19.5	0.04	--	100	19	81
Trichloroethylene (TCE)	125.92	0.90	6.81	0.05	21.6	--	0.05	1.2	0.84	0.4	0.44
Vinyl chloride	87.83	2.99	19.47	0.66	18.9	0.0965	0.22	4.2	--	0.35	--
cis-1,2-Dichloroethylene	309.61	--	6.81	--	61.1	--	0.02	1.3	--	--	--
p-Isopropyltoluene	318.95	--	77.87	--	--	--	0.24	--	--	--	--
sec-Butylbenzene	98.54	--	6.81	--	--	--	0.07	--	--	--	--
trans-1,2-Dichloroethylene	277.91	--	13.63	--	--	--	0.05	--	--	--	--

Notes:

Only detected values are presented.

-- = An IPIMAL was not calculated because there was no toxicity value available. Or, the COPC was not detected.

IPIMAL = Inhalation Pathway Interim Measure Action Level

The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:

Cancer Risk (CR) = 1E-06

Hazard Quotient (HQ) = 0.1

Noncancer = Noncancer-Based IPIMAL

Cancer = Cancer-Based IPIMAL

IA = Indoor Air

AA = Ambient Air

[1]Modeled Indoor Air Concentration = (Maximum Detected Groundwater Concentration) x (Groundwater-to-Indoor Air Volatilzation Factor [GIVF])

Table B-9 – Tier 3 Re-Evaluation for 665 South Lucile Street (11/2003 Sample Results)
Building Type: Commercial

COPC	COPC Detected in Groundwater and Indoor Air: With Corrected Indoor Air Concentration (IA-AA): Commercial Noncancer Exceedance Factor NCEF	With Corrected Indoor Air Concentration (IA-AA): Commercial Cancer Exceedance Factor CEF	With Uncorrected Indoor Air Concentration: Commercial Noncancer Exceedance Factor NCEF	With Uncorrected Indoor Air Concentration: Commercial Cancer Exceedance Factor CEF
1,1,1-Trichloroethane	0.0002	--	0.001	--
1,1-Dichloroethane	--	--	--	--
1,1-Dichloroethylene	--	--	--	--
1,2,4-Trimethylbenzene	--	--	--	--
1,2-Dichloroethane	--	--	--	--
1,3,5-Trimethylbenzene	--	--	--	--
2-Hexanone	--	--	--	--
Benzene	--	--	--	--
Chloroethane	--	--	--	--
Chloroform	--	--	--	--
Ethylbenzene	--	--	--	--
Naphthalene	--	--	--	--
Propylbenzene	--	--	--	--
Tetrachloroethylene	--	--	0.005	0.6
Toluene	--	--	--	--
Trichloroethylene	0.06	8.80	0.1	16.8
Vinyl chloride	--	--	--	--
cis-1,2-Dichloroethylene	--	--	--	--
p-Isopropyltoluene	--	--	--	--
sec-Butylbenzene	--	--	--	--
trans-1,2-Dichloroethylene	--	--	--	--
Total:	**0.06**	**8.8**	**0.13**	**17.4**

Notes:

-- = Not calculated. NCEFs and CEFs were only calculated for COPCs that exhibited a complete exposure pathway for the groundwater to indoor air vapor intrusion pathway (i.e. the COPC was detected in groundwater and indoor air).

IPIMAL = Inhalation Pathway Interim Measure Action Level

The IPIMALs were developed based on a Commercial Exposure Scenario using the following target risk goals for individual COPCs:

Cancer Risk (CR) = 1E-06

Hazard Quotient (HQ) = 0.1

Noncancer = Noncancer-Based IPIMAL

Cancer = Cancer-Based IPIMAL

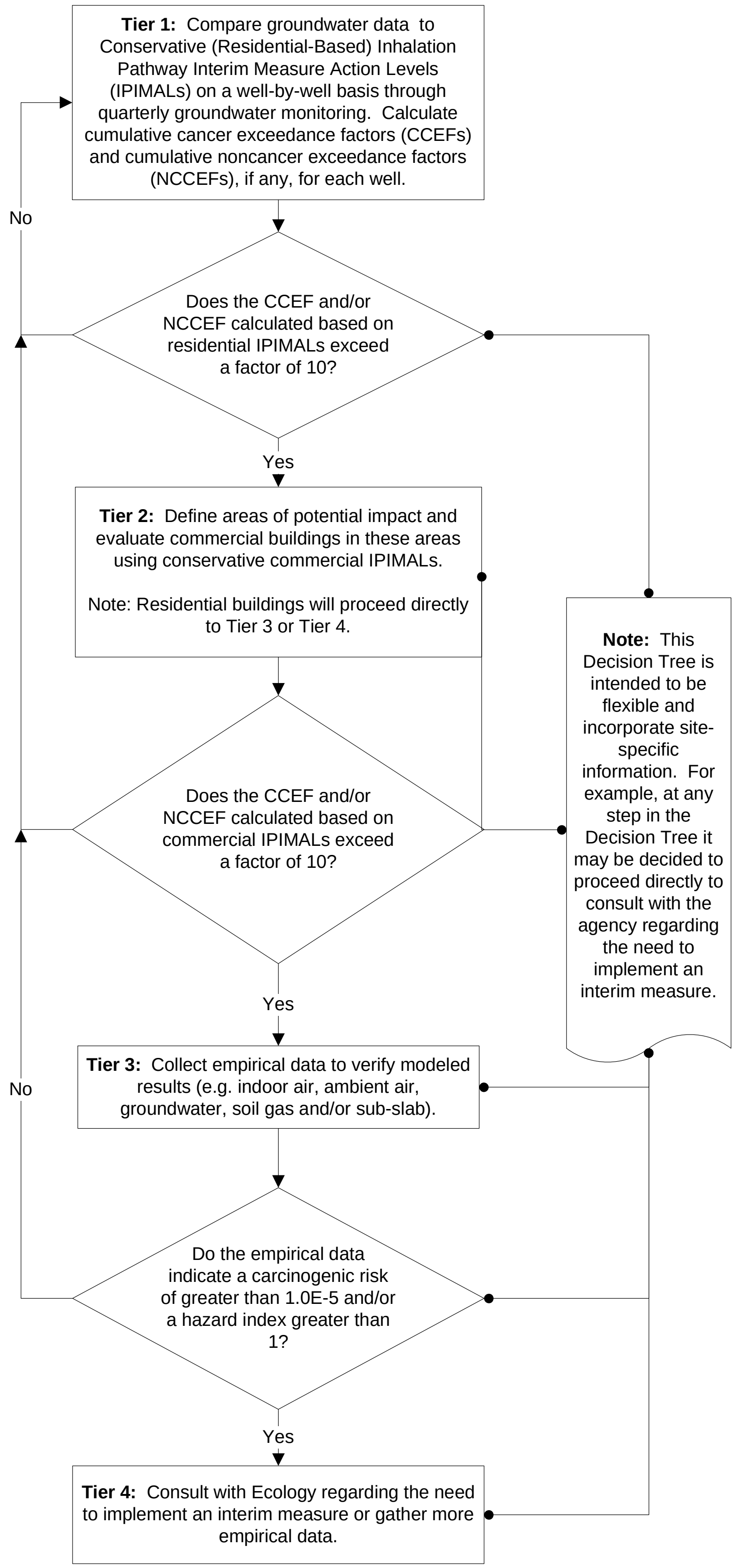
IA = Indoor Air

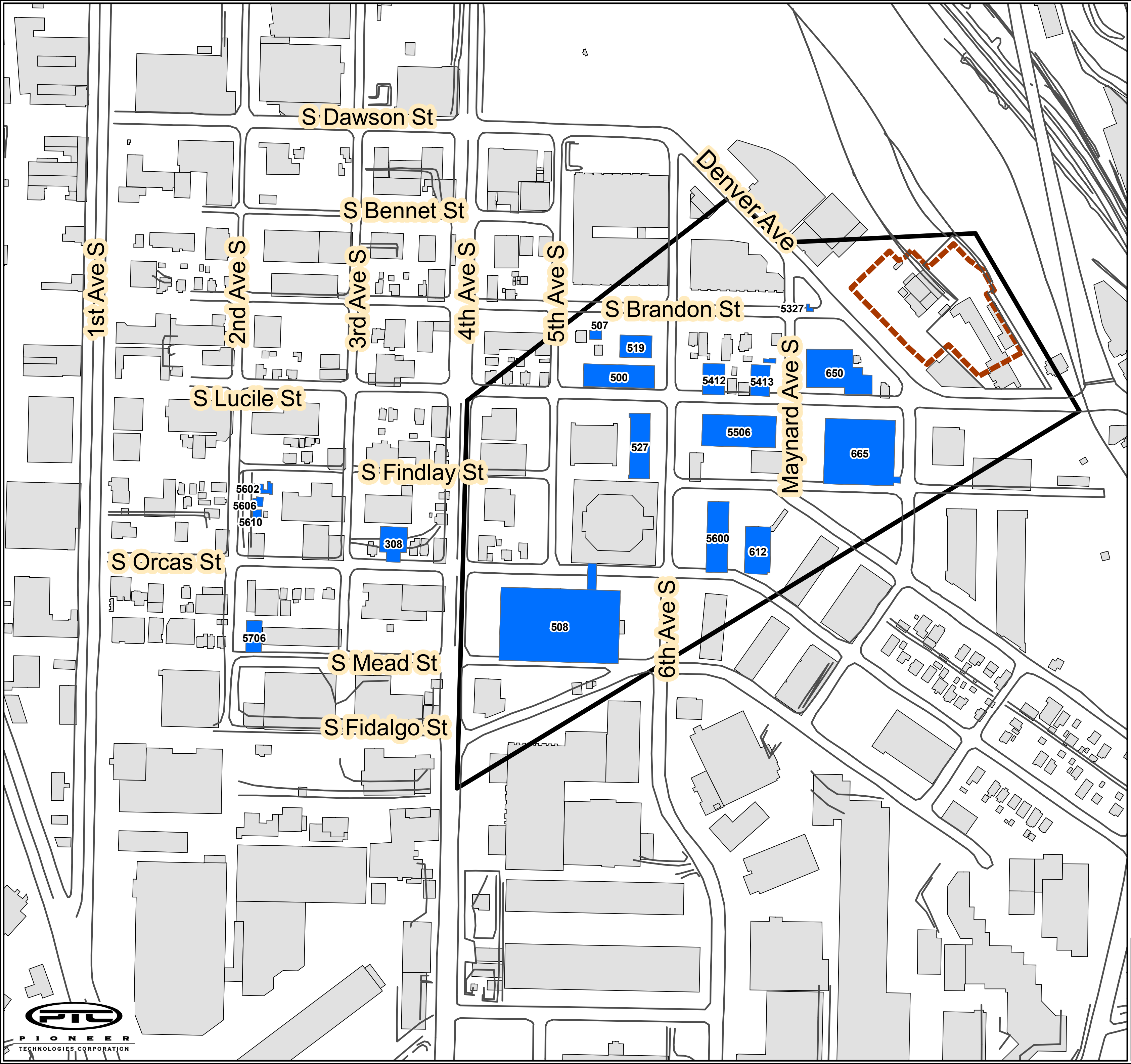
AA = Ambient Air

NCEF = Noncancer exceedance factor = Indoor Air Concentration / Noncancer IPIMAL

CEF = Cancer exceedance factor = Indoor Air Concentration / Cancer IPIMAL

Figure B-1 – IPIM Decision Tree





Legend

- Roads
- Other Buildings
- Tier 3 Locations
- HCIM Area
- Site Wide Feasibilty Study Area

Notes

- HCIM - Hydraulic Control Interim Measure
- IPIM - Inhalation Pathway Interim Measure
- PSC - Philip Services Corporation

IPIM Tier 3 Locations

PSC - Georgetown
May 2006

Figure B-2